Dental Materials Review

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Anecdotal & Marketing Hype

- Condensable composite
- Compomers
- Bonding amalgam
- Nanohybrids
- Rapid light curing
- Antimicrobials
- Universal bonding agents
- Bulk-fill composites
- Resin nano-ceramics

Evidence-Based Dentistry

- Practice of dentistry that integrates
  - the best available evidence
  - clinical experience
  - patient preference

  - in making clinical decisions

Basic Mechanism of Adhesion
(resin-based)

- Exchange process
  - replacement of minerals
    - from hard tissue
  - by resin monomers
    - micromechanically interlocked
- Primarily mechanical
  - retentive interlocking
- Chemical bond
  - mild self-etch with functional monomer

Challenges to Adhesive Dentistry

- Simultaneously treat enamel and dentin
- Work in the presence of moisture
- Technique insensitive
- Biocompatible
- Gap free restorative interface
- Rapidly develop high bond strength

Kugel 2007

Currently Available Generations

- Fourth Generation
  - Three-step Etch & rinse
- Fifth Generation
  - Two-step Etch & rinse
- Sixth Generation
  - Two-step Self-etch
  - One-step Self-etch
    - mix
- Seventh Generation
  - One-step Self-etch
    - no mix
- Eighth Generation?
  - Two-step Etch & rinse or One-step Self-etch

Adhesive Classifications

- **Adhesives**
  - **Etch & Rinse**
    - **Three-Step** etch, prime, bond
    - **Two-Step** etch, (prime & bond)
  - **Self-Etch**
    - **Two-Step** (etch & prime), bond
    - **One-Step** (etch & prime & bond)

Simplified (under the Etch & Rinse Two-Step)

Simplified (under the Self-Etch One-Step)

Van Meerbeek

Pros/Cons of Etch & Rinse

- Separate 37% phosphoric acid etch
  - good enamel etch pattern
- Post-conditioning rinse necessary
  - sensitive to level of dentin wetness

Optibond FL

(Kerr)

- Etchant
  - 37.5% phosphoric acid
- Primer
  - HEMA, GPDM, PAMM, CQ, ethanol, water
- Adhesive
  - Bis-GMA, HEMA, GDMA, EDMAB, silica, CQ

Pros/Cons of Self-Etch

- Good dentin conditioning
  - simultaneous infiltration
    - depth of demineralization
- Possible reduction in post-op sensitivity??
- No post-conditioning rinse
  - not sensitive to level of dentin wetness
- Reduced application time

Pros/Cons of Self-Etch

- Many require refrigeration
- Lower bond strengths to enamel
  - especially uncut enamel

Self-Etch Components

Acidic monomers	MDP Di-HEMA-Phosphate MA 154 Phenyl-P MAC-10 4-MET(A)
Crosslinking monomers	Bis-GMA UDMA TEGDMA GDMA HEMA
Solvent	typically water

Clearfil SE Bond
(Kuraray)

- Primer
  - 10-MDP, HEMA, CQ, water
- Adhesive
  - 10-MDP, bis-GMA, HEMA, hydrophilic dimethacrylate, microfiller

Systematic Review
(Selective Etch)

- Cervical Restorations
- No significant difference
  - retention
- Fewer marginal defects
- Less marginal discoloration
- Improved marginal integrity

- Beveling enamel – no effect
- RD better
- Roughened surface - better bond

Qin J Dent Sciences 2014
Mahn J Adhes Dent 2015
Szesz J Dent 2016

Universal Adhesives

- Etch and rinse, self-etch or selective etch
- Porcelain, ceramic priming
- Simplified adhesives
  - one-step self-etch
  - two-step etch-&-rinse

Perdigao J Adhes Dent 2014

Universal Adhesives

- No clear definition
- Discrepancies
  - single bottle vs. separate components
    - Peak Universal has separate self-etching primer
  - separate dual-cure activator
    - only All-Bond and Futurabond Universal do not require a separate activator
  - separate ceramic primer
    - only Scotchbond Universal contains separate primer to bond to ceramic
      - silane

Raimondi Am J Dent 2016

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    - **One-Step** (etch & prime & bond)

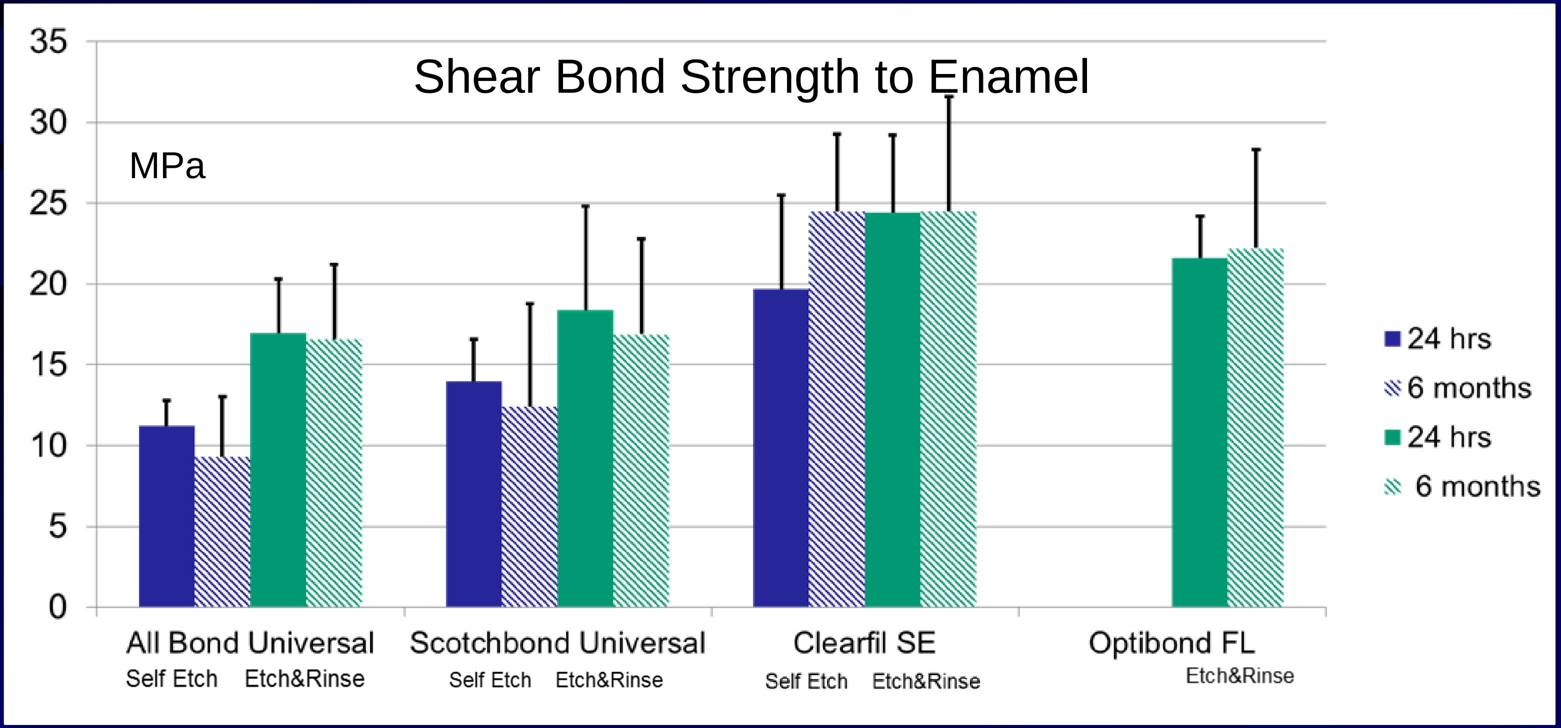
Simplified

Simplified

Van Meerbeek

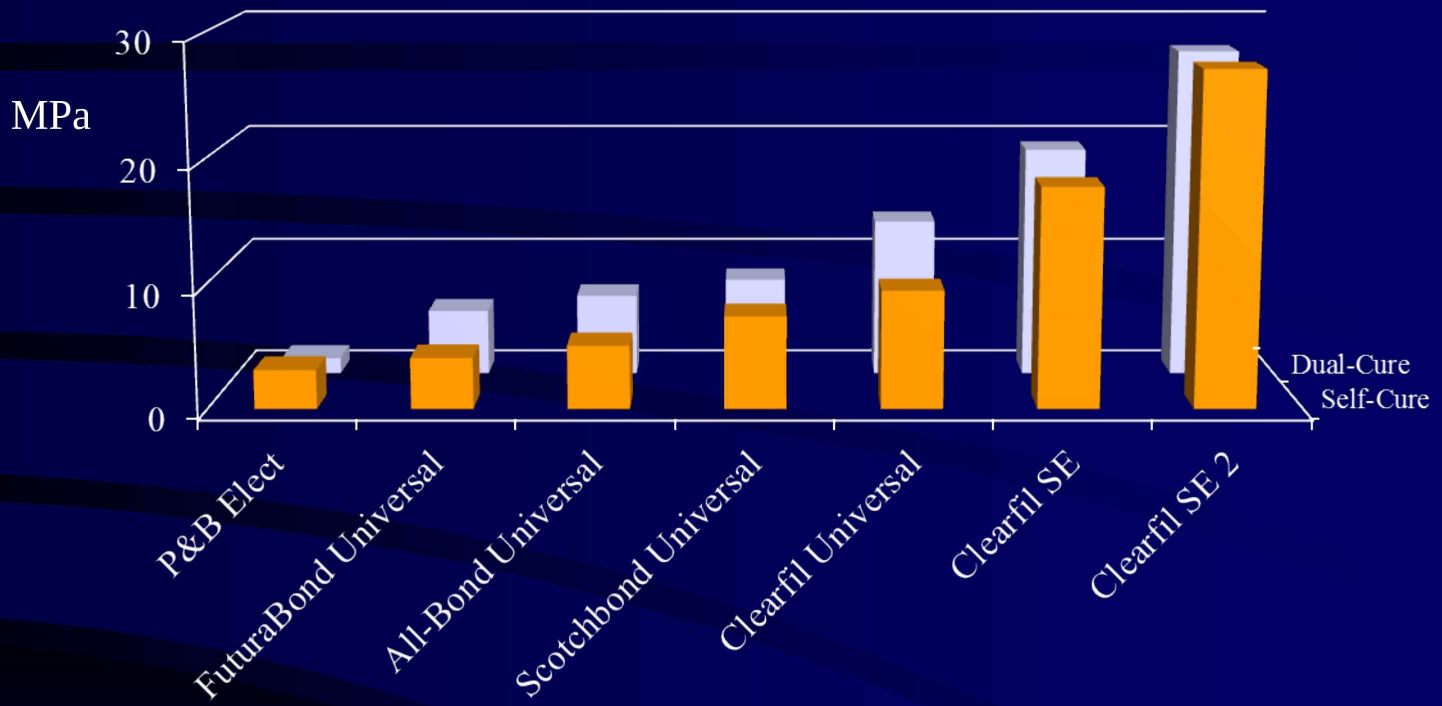
Universal Adhesives

- Reduced bond strength to enamel
  - without separate phosphoric acid etch
  - universal < non-simplified



McLean Oper Dent 2015

Universal Adhesives



- Reduced bond strength to dentin with resin cements
  - universal < non-simplified
  - self-cure < dual-cure

Raimondi Am J Dent 2016

10-MDP Monomer Impurity

- 10-MDP originally developed in 1981 by Kuraray
  - patent expired in 2011
- Recently, MDP has been incorporated into new universal adhesives
- Research suggests poorer bond strength with copy-cat versions

Yoshihara Dent Mater 2015

Universal Adhesives

- Scotchbond Universal
- Reduced bond strength to lithium disilicate
  - without separate silane application
- “Constituent silane in the universal adhesive was not effective in optimizing the ceramic-resin bond”

Kalavacharla Oper Dent 2015

Universal Adhesives

(Two-year Clinical Study)

- Scotchbond Universal vs. MultiPurpose
- NCCLs in 37 patients
- Retention rates
  - Scotchbond MultiPurpose - 87.6%
  - Scotchbond Universal
    - self-etch – 94.9%
    - etch-and-rinse – 100%

Lawson J Dent 2015

Universal Adhesives

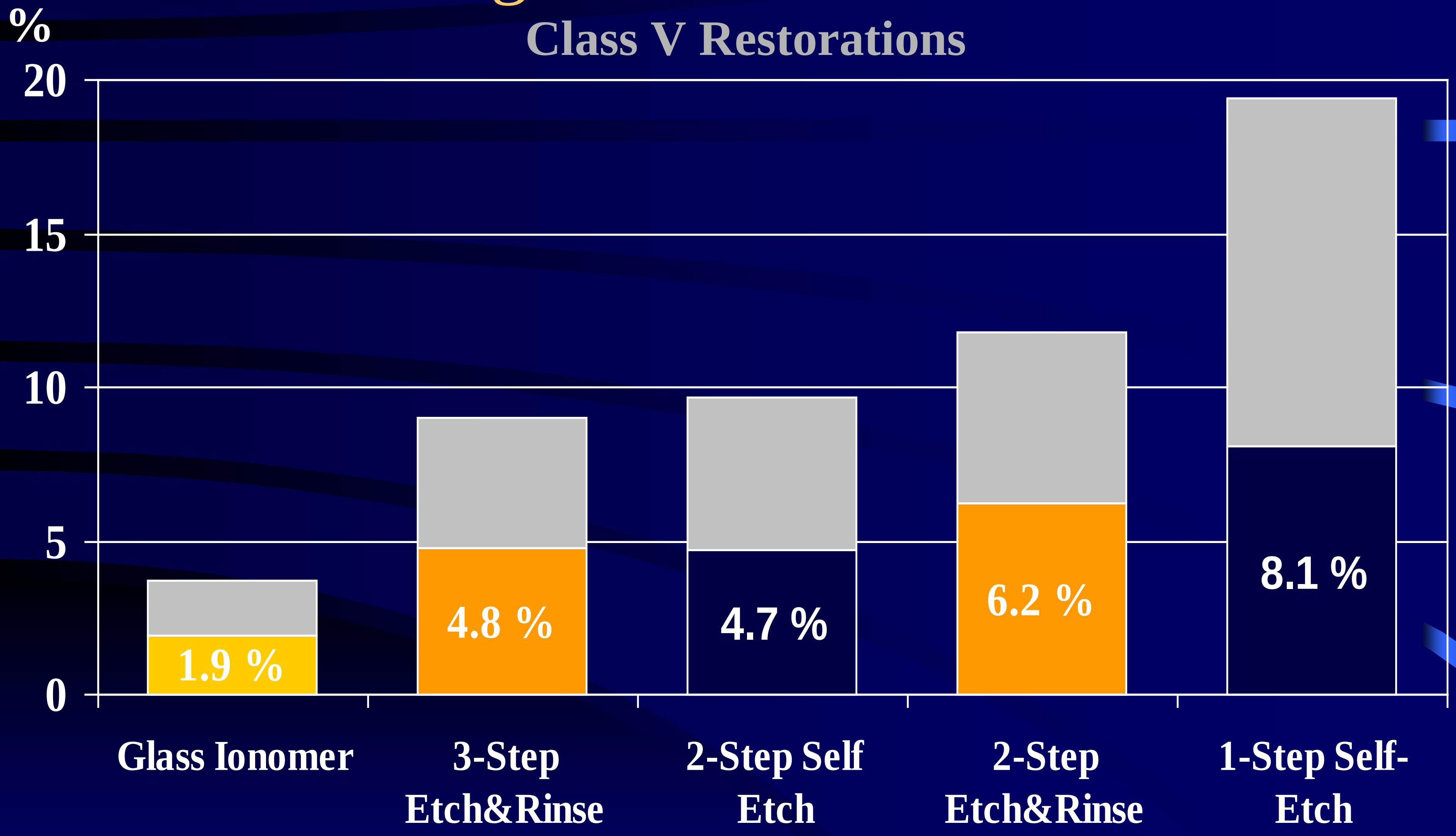
(Clinical Study)

- Scotchbond Universal
  - 200 NCCLs in 39 patients
  - 4 groups
    - etch&rinse, moist dentin (1 lost)
    - etch&rinse, dry dentin (1 lost)
    - selective enamel etch (1 lost)
    - self-etch (5 lost)
  - 36-month recall
  - significantly more marginal discrepancy
    - self-etch group
- "…they will likely undergo the same degradation pattern observed with older simplified bonding agents"

Loguercio J Dent 2015
Perdigao J Adhes Dent 2014

Average Annual Failure Rate

Class V Restorations



Peumans Dent Mater 2005

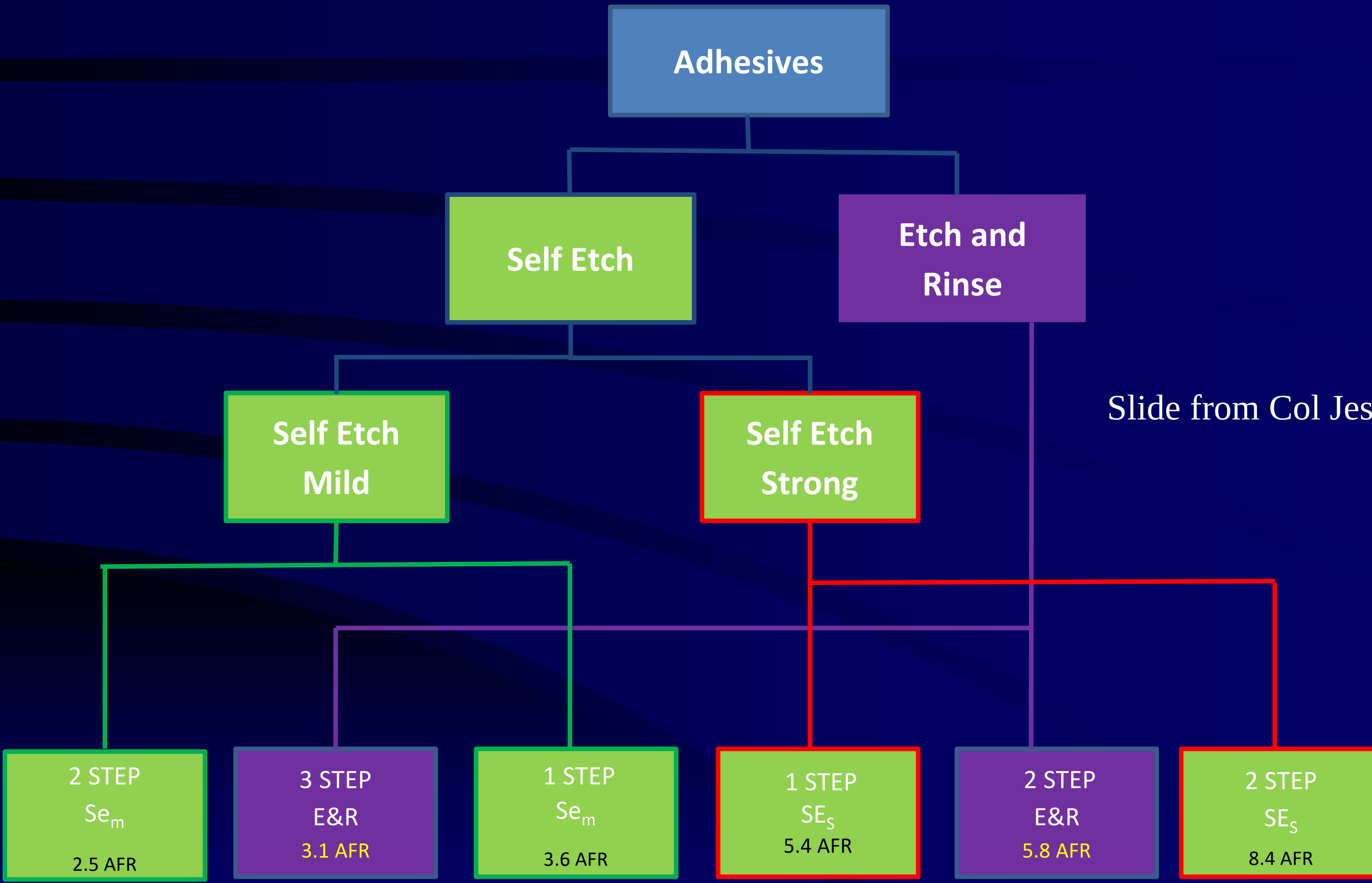
Cervical Restorations
(Meta Analysis)

- Clinical performance
  - Two-step, self etch
  - Three-step, etch and rinse
  - Glass ionomers
  - Resin-modified glass ionomers
  - Two-step, etch and rinse
  - Polyacid-modified composite resins
  - One-step, self etch

Heintze Dent Mater 2010

Systematic Review

Cervical Restorations

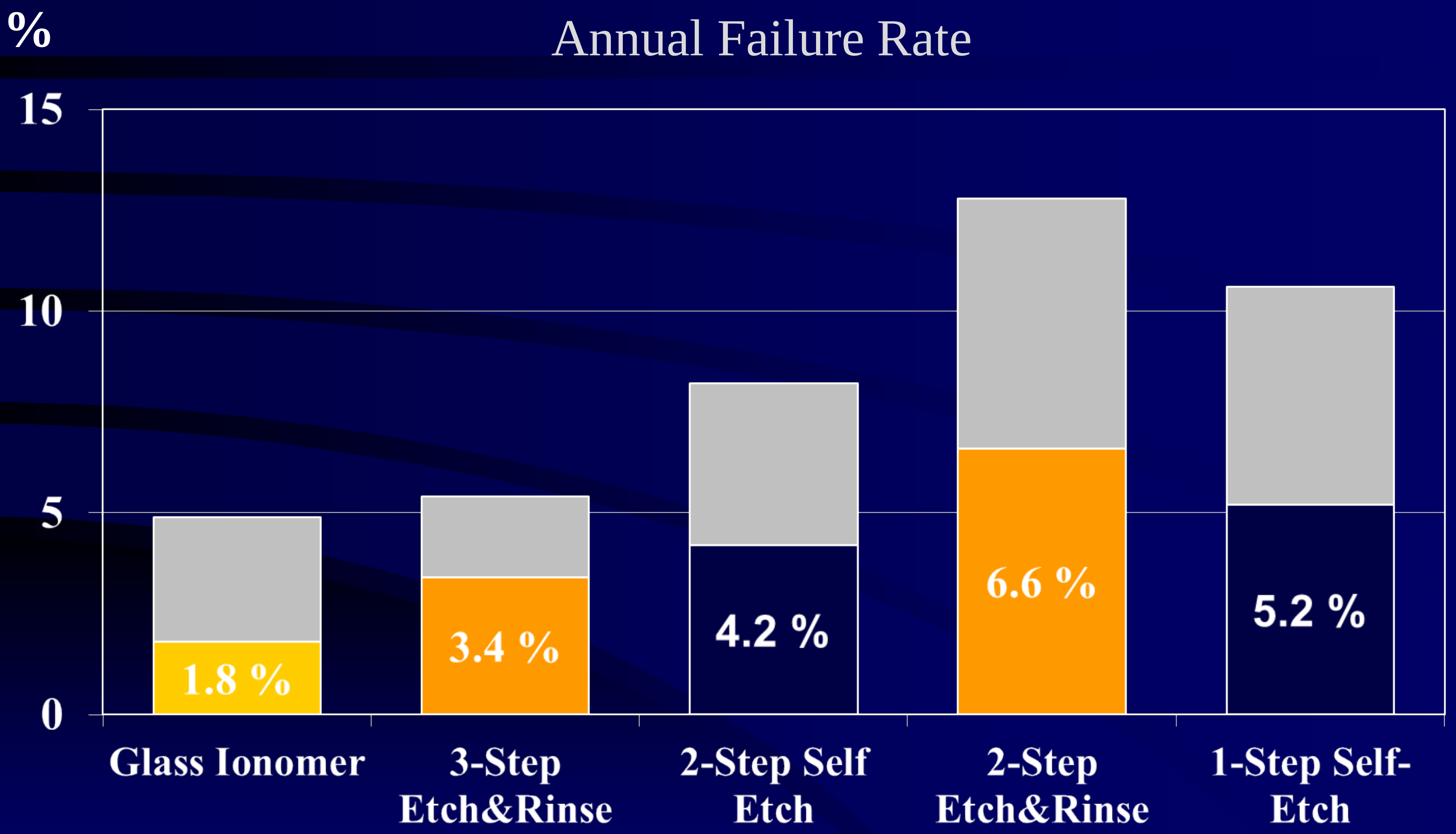


Slide from Col Jessup

Peumans Dent Mater 2014

Systematic Review

Cervical Restorations
Annual Failure Rate

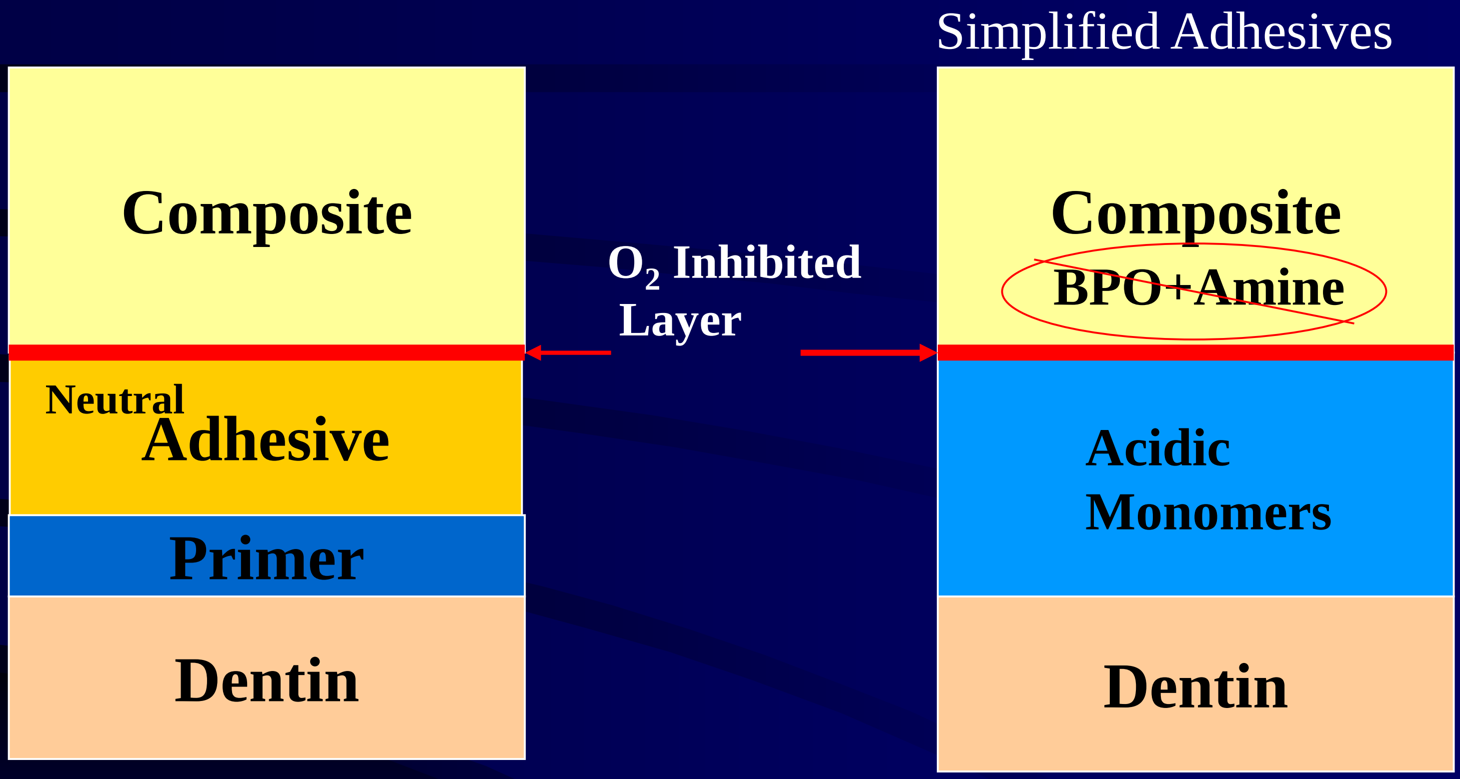


Schwendicke JDR 2016

Incompatibilities

- Self-cure composites
  with simplified adhesives
  - two-step etch & rinse
  - one-step self-etch
- Acidic monomers react with basic catalyst of overlying composite
- Adhesive permeability leads to superficial water blisters via water trees

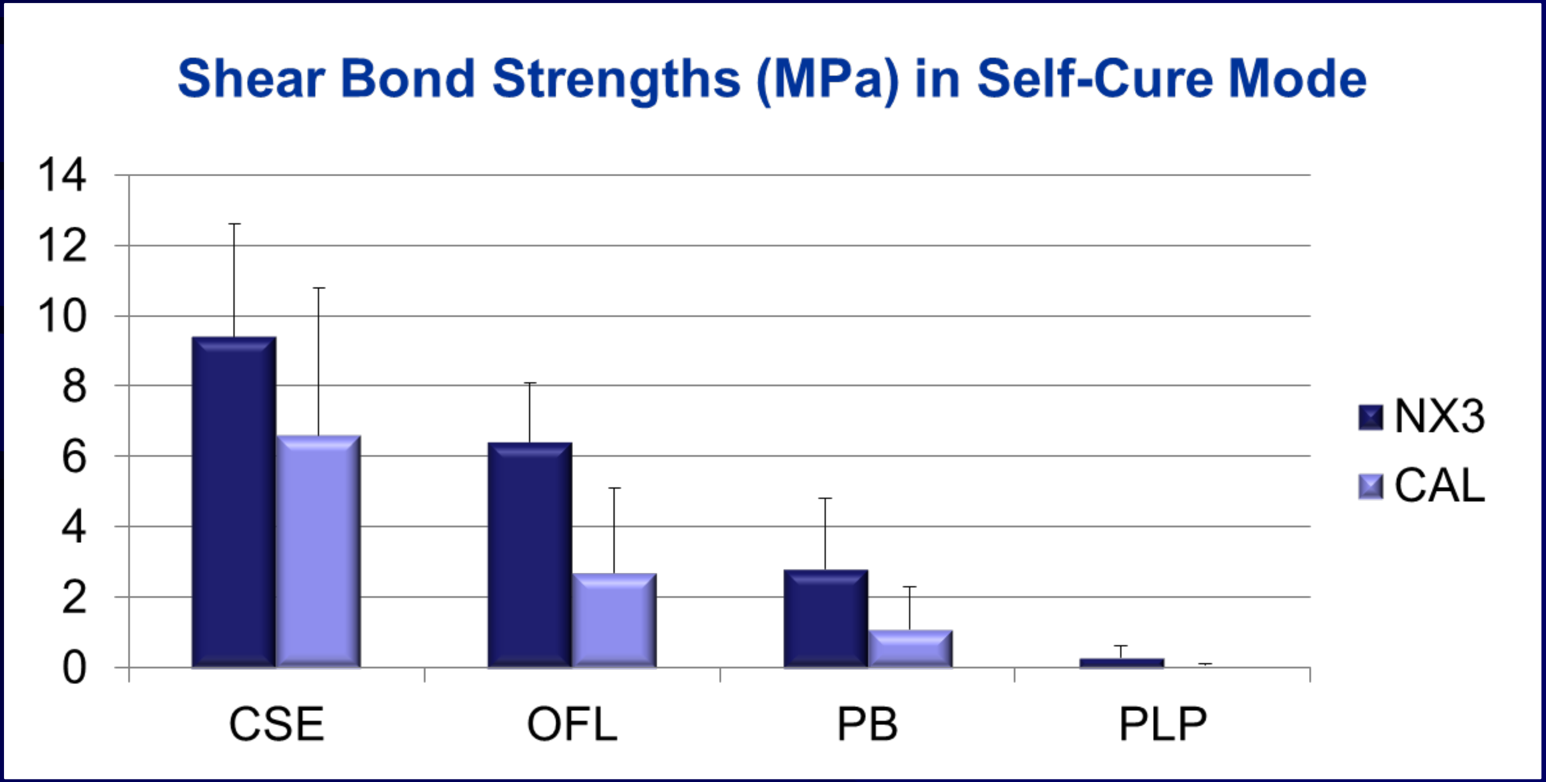
Adverse Acid-Base Reaction



Three-step Etch & Rinse
Two-step Self-Etch

Two-step Etch & Rinse
One-step Self-Etch

Laboratory Study



Shade Oper Dent 2014

Survival of Ceramic Inlay/Onlay Restorations

Practice-Based Research Network

- 3-year mean observation time
  - maximum 15 year
- 5791 ceramic inlay/onlays
  - 167 dentists & 5523 patients
    - 1994 - 2014
- Simplified bonding agents
  - 142% greater failure rate compared to
- Non-simplified bonding agents
  - "…hydrophobic layer of gold-standard adhesives increases the stability of the bonds to dental tissues."

Collares Dent Mater 2016

Enzymatic Degradation

- Matrix metalloproteinases (MMPs 2, 8, 9)
- Cysteine cathepsins
  - endogenous enzymes
  - collagenolytic
- Inhibitors
  - chlorhexidine
    - reduces interfacial aging over time (in vitro)
      - especially two-step etch and rinse
      - self-etch somewhat equivocal
    - applied after acid etching
      - acidic conditioner, rinse, dry, chlorhexidine , dry, primer, dry, adhesive, cure

Reis Oper Dent 2013

Systematic Review

MMP Inhibition

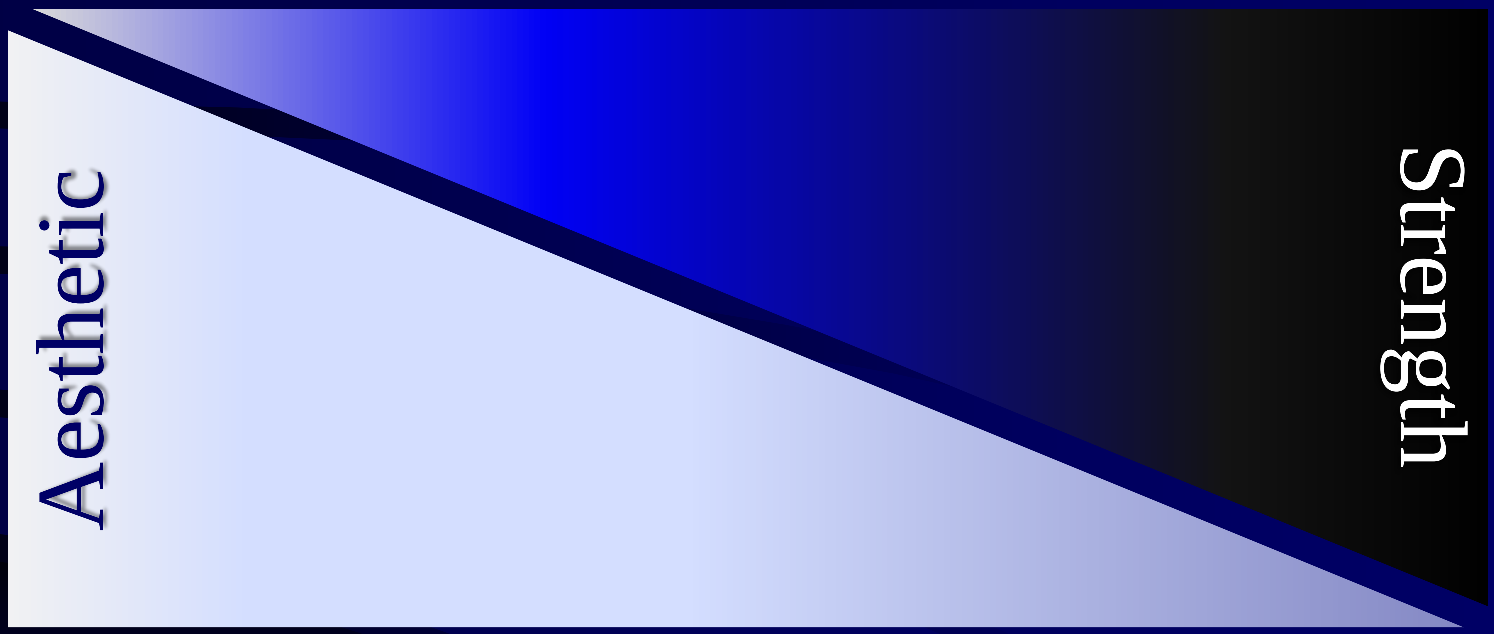
- Ten clinical studies
  - 695 Class I or V restorations in 208 patients
    - chlorhexidine (7)
    - ethanol-wet bonding (2)
    - quaternary ammonium compounds (1)
- 6 – 36 month follow-up
- Beneficial effect is not supported by evidence
- Impact of disinfection remains unclear

Gostemeyer J Dent 2016

Classifications

- Microstructure
  - amount and type
    - glass and crystalline phase
- Processing technique
  - powder – liquid
  - pressed
  - machined
- Clinical application

Ceramic Spectrum



GB	GB-CF	CB-GF	PC
Glass-Based	Glass-Based with Crystalline-Fillers	Crystalline-Based with Glass-Fillers	Polycrystalline

Slide from Maj Vandewalker

Microstructure

- Dispersion Strengthening
  - Leucite ($K_2O \cdot Al_2O_3 \cdot 4SiO_2$)
  - Lithium Disilicate ($Li_2O \cdot 2SiO_2$)
  - Magnesia-Alumina Spinel ($MgO \cdot Al_2O_3$)
  - Alumina (Al_2O_3)
  - Zirconia (ZrO_2)

Kelly JADA 2008

1. Glass-Based Systems

- Mainly silicon dioxide
  - silica, quartz
  - feldspar
    - alumino-silicates
      - various amounts of potassium, sodium
- Machinable blocks
  - Vita Mark II
    - fine grain
  - RealLife
- Porcelain veneers
  - refractory die
- Veneering porcelain

2. Glass-Based Systems with Fillers

- Glass composition similar to glass-based
- Three subcategories
- Crystals have either been added or grown
  - Leucite (low or high)
    - increased potassium oxide content of alumino-silicate glass
  - Lithium disilicate
    - adding lithium oxide to alumino-silicate glass

2. Glass-Based Systems with Fillers

Subcategory 1

- Low-moderate leucite-containing feldspathic glass
  - known as “feldspathic porcelain”
- Typically powder-liquid
  - veneer core systems
    - Vita VM 13
  - porcelain veneers

2. Glass-Based Systems with Fillers

Subcategory 2

- High leucite-containing glass
  - approximately 50%
  - also called “glass ceramic”
    - crystalline phase grown with the glass
- Powder / liquid
- Pressable
  - IPS Empress Esthetic (Ivoclar)
- Machinable
  - Empress CAD (Ivoclar)

Pressable Ceramics

- IPS Empress Esthetic (Ivoclar)
- Leucite-reinforced
  - inhibits crack growth
  - etchable
  - excellent esthetics
- Anterior crowns/inlays/onlays/veneers

Kelly Dent Clin N Am 2004

Machinable Ceramics

- IPS Empress CAD (Ivoclar)
- Leucite-reinforced
  - flexural strength = 120 MPa
- Variety of opacities
  - HT – high translucency, for inlays/veneers
  - LT – low translucency, for onlays/crowns
- Anterior crowns/inlays/onlays/veneers

2. Glass-Based Systems with Fillers

Subcategory 2

- IPS Empress CAD
- Multi-block
  - transitional shade

2. Glass-Based Systems with Fillers

Subcategory 3

- Lithium-disilicate glass ceramic
  - lithium-oxide crystals added
    - 2/3rds of volume
    - doubles the strength
- Pressable
  - e.max Press (Ivoclar)
- Machinable
  - e.max CAD (Ivoclar)

Pressable Ceramics

- IPS e.max Press (Ivoclar)
- Lithium disilicate
  - 70% lithium disilicate ($Li_2O \cdot 2SiO_2$)
  - relatively translucent

- Anterior/posterior crowns/onlays anterior FDPs

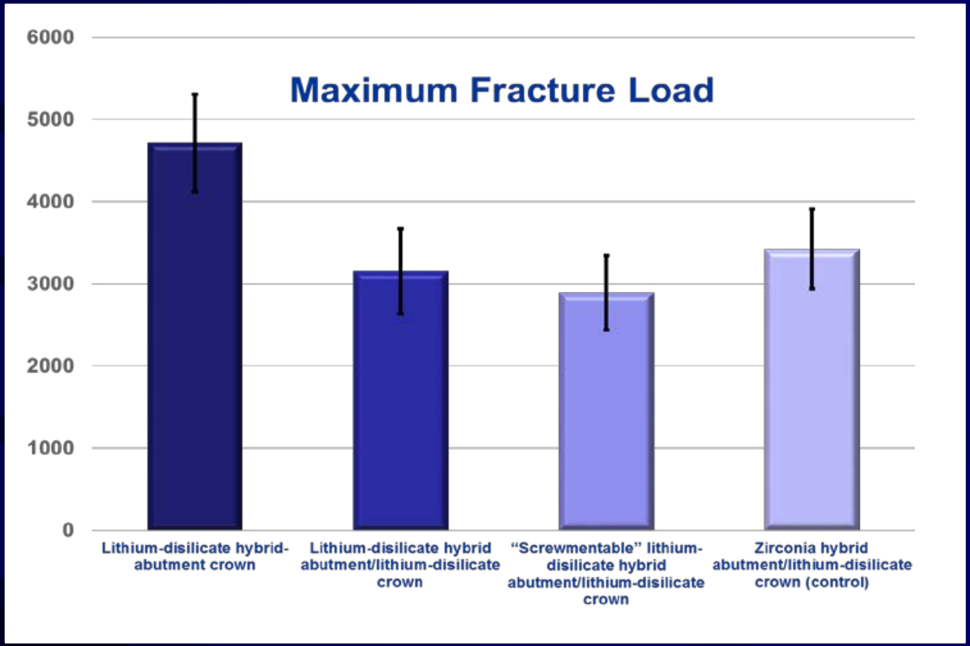
Machinable Ceramics

- IPS e.max CAD (Ivoclar)
  - lithium disilicate
  - “blue block”
- Milled
- Crystallized in oven
  - 30 minutes
- Flexural strength = 360 MPa
- Variety of opacities:
  - HT – high translucency
  - LT – low translucency
  - MO – medium opacity for layering
- Anterior/posterior crowns/onlays anterior FDPs

IPS e.max CAD

- Six clinical studies lasting up to 4 years
  - 237 restorations (crowns)
    - Richter et al., 2009; Nathanson, 2008; Reich et al., 2010; Fasbinder et al., 2010; Bindl, 2011; Sorensen et al., 2009
  - 97.9% of the restorations survived
  - failure rate of 2.1%
    - 0.4% irreparable chipping
    - 1.7% fractures

Fracture Strength



Roberts IADR 2017

Machinable Ceramics
(Lithium Silicate)

- Celtra Duo (Dentsply)
  - zirconia reinforced lithium silicate
  - two options
    - with or without crystallization
- Suprinity (Vita)
  - zirconia reinforced lithium silicate
- Obsidian (Glidewell)
  - lithium silicate and lithium phosphate

3. Crystalline-Based Systems with Glass Fillers

- Sintered crystalline matrix
  - 85% of volume
  - junction of particles in crystalline phase
  - alumina/magnesia, alumina, alumina/zirconia
- “Slip casting” or milled
- Infiltrated with glass
- In-Ceram (Vita)

4. Polycrystalline Solids

- Solid-sintered monophase ceramics
  - dense, air-free, glass free
  - high strength, high shrinkage (20%)
- Aluminum oxide
  - frameworks
- Zirconia oxide
  - frameworks, monolithic
- Crowns, FDPs, implant abutments

4. Polycrystalline Solids

- Zirconium Oxide
  - IPS e.max ZirCAD (Ivoclar)
  - Lava (3M ESPE)
- Oversized coping
  - milled from partially sintered zirconia oxide block
- Sintered
  - shrinks to fit die
- Veneering porcelain
- Flexural strength (1100 MPa)

4. Polycrystalline Solids

- Ivoclar
  - e.max ZirCAD
    - 3Y-TZP
  - e.max Ceram
    - fluorapatite veneering ceramic
  - e.max ZirPress
    - fluorapatite glass-ceramic
  - ZirPress vs. Ceram
    - no difference in failure load
      - » *Tsalouchou 2008*

4. Polycrystalline Solids

- InCoris ZI meso (Sirona)
  - zirconia abutment block
- Ti-base (Sirona)

Zirconia

- Three Phases

- Stabilization of Tetragonal Phase
  - Yttrium cation-doped tetragonal zirconia polycrystal (3 mol%, 3Y-TZP)

Zirconia - Unknowns

- Unwanted phase transformation
    - metastable tetragonal phase into monoclinic phase
  - Abrasion
    - air-abrading the internal surfaces
    - adjusting for fit
    - grinding on external surfaces
  - Low temperature degradation (LTD)
    - hydrolytic degradation
    - no direct correlation
      - between LTD and clinical failure in dentistry

Harding J Prosthodont 2012

Veneer Chipping

- Metal-ceramic
  - 2.5% - 3.2% in 10 years
  - Reuter 1984, Tan 2004
- Zirconia-ceramic
  - 4.3% (18 months)
  - 15% (2 years)
  - 6% (38 months)
    - Bonermann 2003, Vult von Steyern 2005, Tinschert 2005

Zirconia - Concerns

- Chipping of veneering porcelain
  - mismatch coefficient of thermal expansion
  - mismatched thermal conductivity
    - temperature gradient during cooling
  - phase transition
    - liquid silicate penetration of zirconia grain boundaries
  - poor support of veneering porcelain
    - lack of anatomic coping

Kimmich JADA 2013

Other Applications

- e.max CAD-on (Ivoclar)
  - milled core and milled veneer
    - zirconia core
    - lithium disilicate veneer

- 29 three-unit FDPs - 2 studies
  - mean observation period was 21 months
  - so far no failures have occurred
    - Watzke et al., 2012; Blatz et al., 2012
- 40 IPS e.max CAD-on crowns
  - no failures were observed up to 36 months
    - Watzke et al., 2012

Renda J Pros 2015

Zirconia Monoblock

- Eliminate veneering ceramic
  - favorable enamel antagonist
    - polished full-contoured zirconia crown
      - *Preis 2011, Preis 2012, Stawarczyk 2013, Janyavula 2013, Park 2014*

Zirconia Monoblock

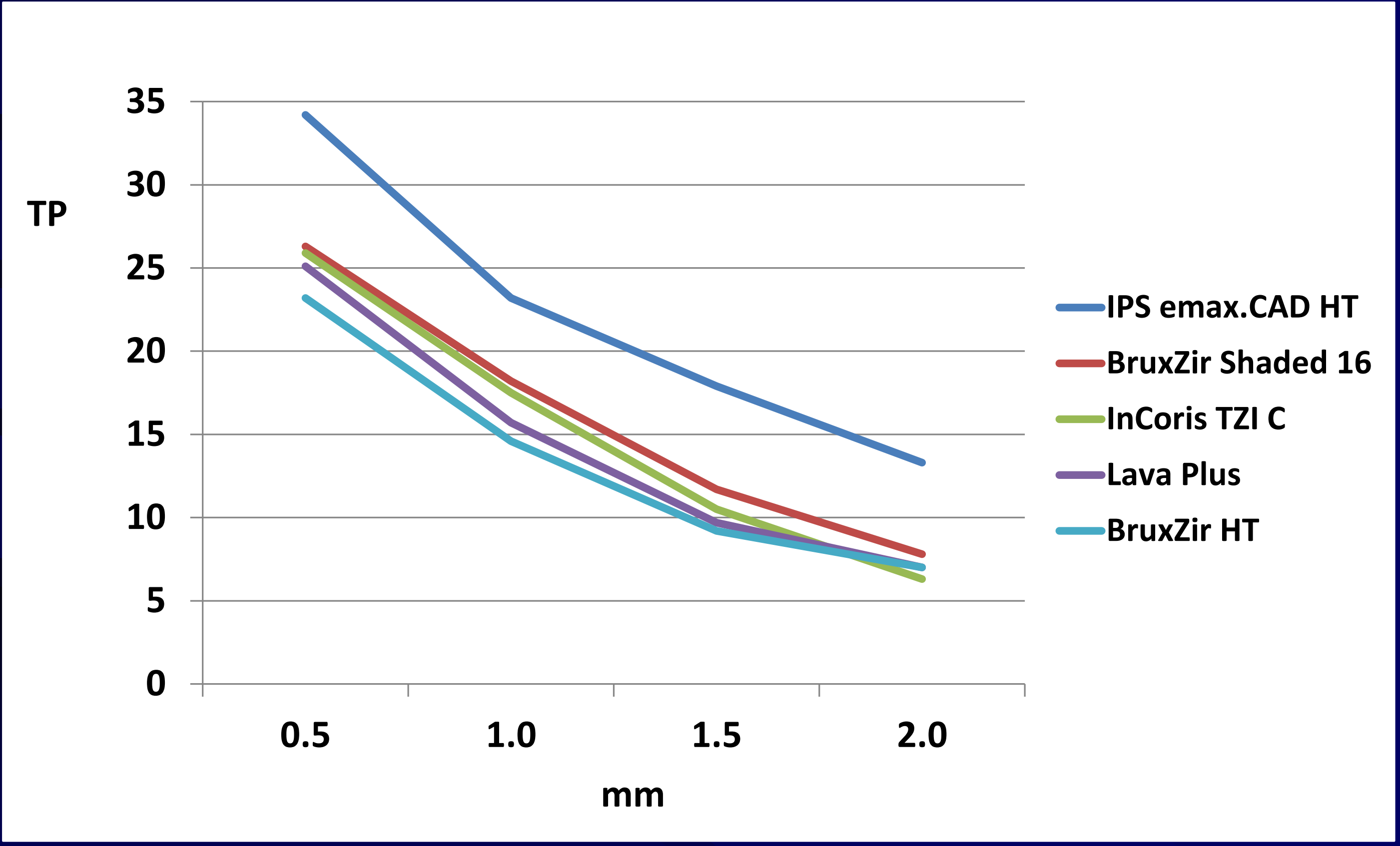
– BruxZir (Glidewell Labs)
– Lava Plus (3M ESPE)

Increasing Translucency

- Reducing porosity
- Decreasing grain size
- Adjustments to sintering parameters

- BruxZir Shaded (Glidewell)
- InCoris TZI (Sirona)

Translucency of Newer Translucent Zirconia



Church Accepted for Publication

cubeX^2

- Cubic zirconia (Dental Arts)
  - stabilized 5-mol% yttria oxide
  - 53% cubic / 47% tetragonal
  - increased translucency
  - flexural strength – 700 MPa

Same-Day Zirconia Restorations

- BruxZir Now (Glidewell)
  - pre-shaded, fully sintered zirconia milling
  - TS15 in-office mill from IOS Technologies
  - iTero, 3Shape TRIOS and 3M True Definition Scanner
- CEREC Zirconia (Sirona)
  - pre-shaded translucent zirconium oxide
  - sintering process - 10-15 minutes
    - CEREC SpeedFire furnace

All-Ceramic Spectrum

	Toughness	**Application**
Feldspathic		
Leucite Reinforced Porcelains	**1.3 MPa(m$^{1/2}$)**	Veneers/ inlays/ onlays/ anterior crowns/ posterior crowns ? MUST BE BONDED
Lithium Disilicate Glass Ceramics	**2.5-3.4 MPa(m$^{1/2}$)**	Single-unit crowns/ 3-unit FPD's CAN BE BONDED
Glass Infiltrated Aluminous Cores	**~2.5 MPa(m$^{1/2}$)** (Spinel) **3.4-4.9 MPa(m$^{1/2}$)** (Alumina) **4.8-6.0 MPa(m$^{1/2}$)** (Zirconia)	Anterior crowns (Sp, Al, Zr) Posterior crowns (Al, Zr only) Anterior FPD (Al, Zr only) Posterior FPD (Zr only)
Polycrystalline Solids	**3.8-4.0 MPa(m$^{1/2}$)** (Alumina) **6.0-8.0 MPa(m$^{1/2}$)** (Zirconia)	Substructure for single or multi-unit anterior or posterior

Maj Cade Salmon

Ceramic / Polymer

- Lava Ultimate (3M/ESPE)
  - nano-ceramic particles (80% wt) embedded in a highly cross-linked resin matrix (20% wt)
- Vita Enamic (Vident)
  - hybrid ceramic with dual-network structure
    - polymer-infiltrated ceramic network

Ceramic / Polymer

- CeraSmart (GC)
  - flexible nano-ceramic resin
  - 71% silica / barium glass nanoparticles by wgt

Ceramic / Polymer

- Higher strength/toughness
  - feldspathic, leucite-reinforced
- More flexible
  - feldspathic, leucite-reinforced

J Clin Exp Dent. 2015
Awada J Prosthet Dent 2015

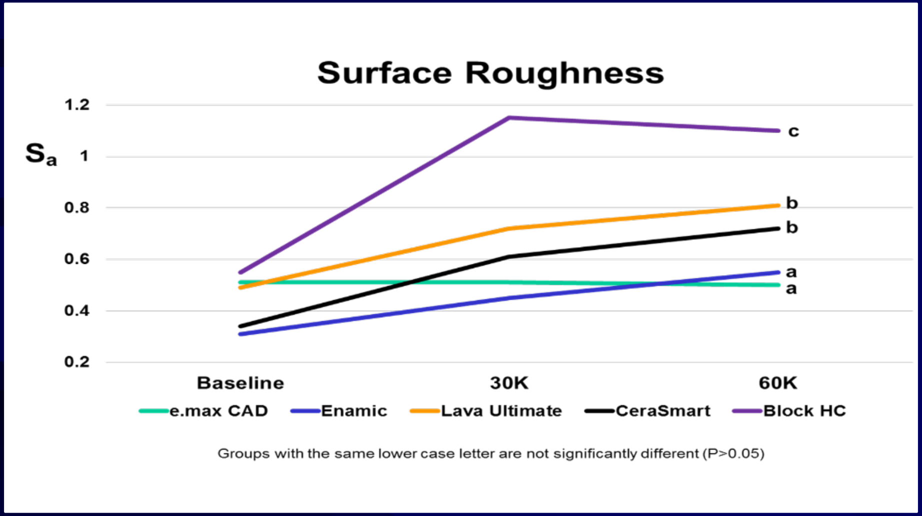
Ceramic / Polymer

- Less brittle than glass-ceramics
  - less prone to cracking
    - try-in/function
  - better edge quality

Awada J Prosthet Dent 2015

Ceramic / Polymer

- Decreased cement bond to nano-ceramic?
- Difficulty in maintaining surface gloss?



Partin IADR 2017

Ceramic / Polymer

(Clinical Study)

- 25 Lava Ultimate vs. 25 Empress CAD crowns
- Five Lava Ultimate debonded
  - between 6 months and 1 year
    - Fasbinder AADR 2014

- “3M ESPE Dental is removing the crown indication for Lava™ Ultimate CAD/CAM Restorative product because crowns are debonding at a higher-than-anticipated rate. The product continues to be indicated for inlays, onlays (with an internal retentive design element) and veneer restoratives”

Ceramic / Polymer
(Retrospective Clinical Study)

- 45 Vita Enamic crowns
  - 35 patients
- >90% estimated 2-yr survival
  - 2 failures

Chirumamilla J Esthet Restor Dent 2016

Clinical Performance

- Comparison of results is challenging
  - different materials
  - reporting of complications
  - study conditions
  - evaluation times
- Fracture – most reported complication
  - veneering porcelain
  - ceramic coping

Single Crowns

Systematic Review

- Sixty-seven studies
  - 4663 metal-ceramic / 9434 all-ceramic crowns
- Estimated 5-year survival
  - metal-ceramic – 94.7%
  - feldspathic / silica glass
    - anterior – 94.6%
    - posterior – 87.8%
  - reinforced glass – 96.6%
  - glass-infiltrated – 94.6%
  - zirconia – 91.2%
    - veneering porcelain fractures and debonding

Sailer Dent Mater 2015

In conclusion…

- Metal / metal-ceramic crowns
  - still the gold standard
  - excellent physical properties
  - esthetics?
- All-ceramic
  - know the limits
  - understand the material
  - recognize acceptable situations

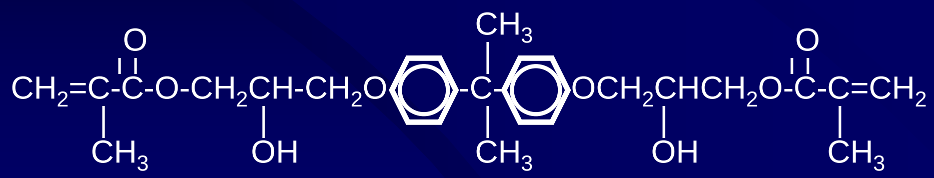
Photo-polymerization & Dentistry

- 130,000 general dentists
- Over 500 million direct dental restorations are placed each year worldwide
  - 55% are resin composites or compomers

Heintze Dent Mater 2015

Visible-Light Activation

- Visible light
  - 400 – 700 nm
- Photo-initiator in resin
  - absorbs photon energy
  - combines with activator
    - amine
  - creating free radicals
  - initiates polymerization
    - monomer
      - Bis-GMA



Photopolymerization

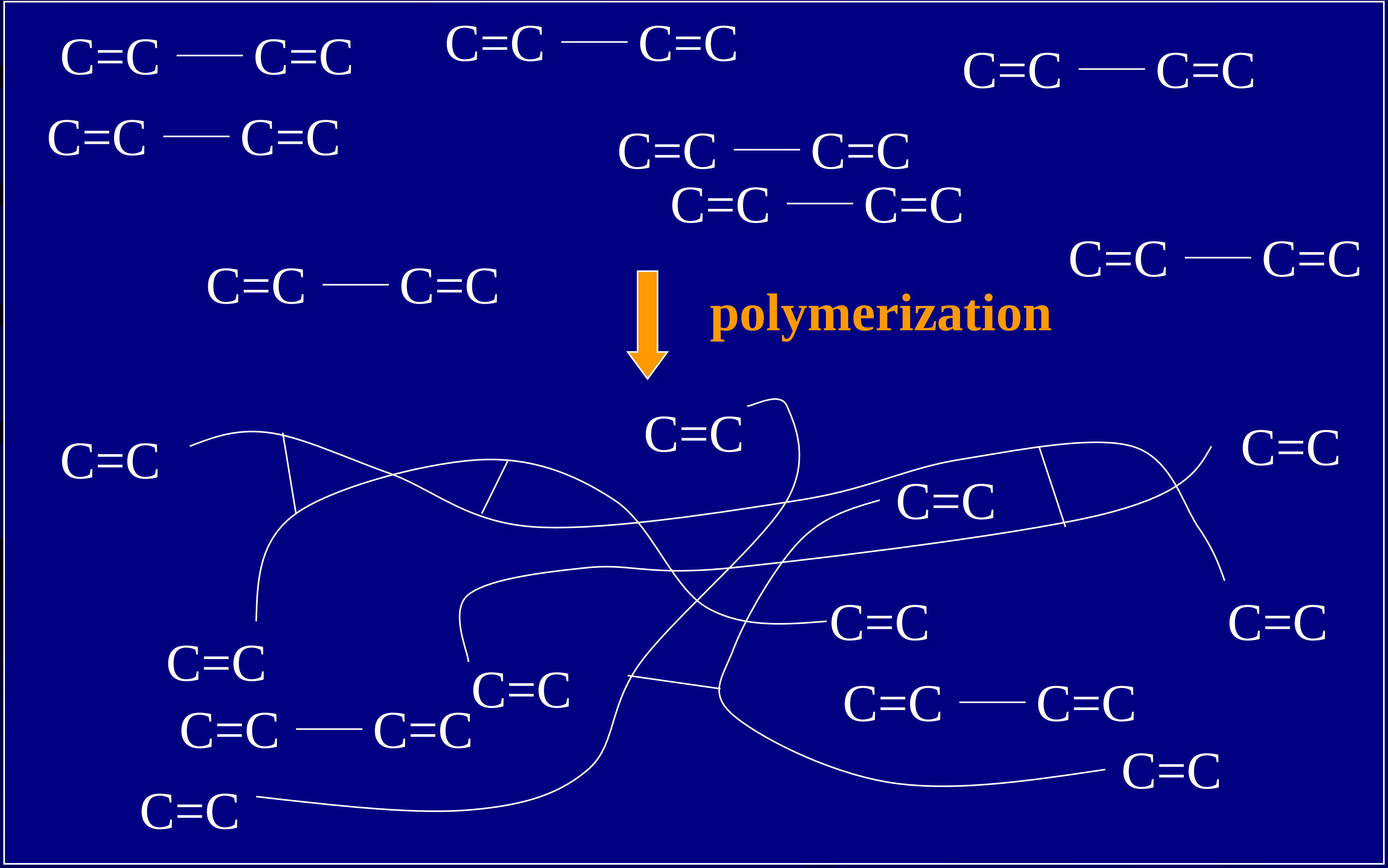
- Camphorquinone (CQ)
  - most common photo-absorbing material
  - maximum sensitivity
    - blue range
      - 400-520 nm
        - » peak at 468 nm

Polymerization

- Initiation
  - production of reactive free radicals
  - chemical, light, heat
- Propagation
  - monomer units
  - polymer network
  - 50 – 60% degree of conversion
- Termination

Ferracane Crit Rev Oral Biol Med 1995

Polymerization



Ferracane Crit Rev Oral Biol Med 1995

Energy Sources

- Halogen
- Plasma-arc
- Argon laser
- LED

Light-Emitting Diodes (LEDs)

- Indicator lights
  - electronic equipment
- Small displays
- Illumination
- Traffic signs
- Televisions
- Projectors
- Light bulbs

Light-Emitting Diodes (LEDs)

- Curing lights
- Head lights
- Dental unit lights

Light-Emitting Diodes (LEDs)

- Semiconductor material
  - gallium-nitride
    - blue
- Electrically-excited atoms
- Narrow spectrum

LED Curing Lights

- Typically single spectrum
  - 430 – 490 nm
    - near absorption maximum of camphorquinone
- Long lasting light source
  - minimal bulb aging
  - shock resistant
- Less lateral heat production
- Efficient
  - cordless

Kramer Am J Dent 2008

Initiator-Light Incompatibilities

- Narrow spectrum lights
  - argon laser
  - LED
- Other photoinitiators absorb at lower wavelengths
  - PPD (phenylpropanedione)
  - TPO (trimethylbenzoyl diphenylphosphine oxide)
- Narrow spectrum lights may not polymerize materials containing other initiators

Van Landuyt Biomaterials 2007

Composite Photo-initiators

- Blue spectrum photo-initiators
  - Camphorquinone (CQ)
    - most common
    - 469 nm
- Violet spectrum photo-initiators
  - Phenylpropanedione (PPD)
    - 398 nm
  - Monoacylphosphine oxide (Lucirin TPO)
    - 381 nm
  - Bisacylphosphine oxide (Irgacure 819)
    - 370 nm

Neumann J Dent 2005

Initiator-Light Incompatibilities

- PPD, TPO photoinitiators less yellow than camphorquinone
- Products
  - – Biscover (Bisco)
  - – TempGlaze (Clinician’s Choice)
  - – Principle (Dentsply)
  - – Composites
    - bleaching, translucent shades
      - – Tetric Evo Ceram (Ivoclar)

Third Generation LED Lights

- Dual-emission spectrum
  - reportedly cures all photo-initiated materials
    - UltraLume 5, Valo (Ultradent)
    - Bluephase G2, 20i (Ivoclar)
    - Fusion (Dentlight)
    - SmartLite Max (Dentsply)

Purchasing Considerations

- 145 different models worldwide
  - 42 manufacturers
- \$27 - \$4,900
- 400 – 5,000 mW/cm^2
- Five modes & six different curing times
- One second to 20 seconds or more of curing time
- Light guides vs lenses
- Air cooled, water cooled or no cooling system

Single-Spectrum LED

- Demi Plus (Kerr)
  - – lithium-ion battery
  - – fan with vents
  - – cordless
  - – multiple curing times
- Demi Ultra (Kerr)
  - – U-40 Ultracapacitor Technology
    - re-energizes to full power in under 40 seconds
      - – 25 ten-second cures
    - does not require replacement
  - – fanless with no vents
  - – cordless
  - – multiple curing times

Single-Spectrum LED

- Paradigm Deep Cure (3M ESPE)
  - lithium-ion battery
  - fanless
  - cordless
  - multiple curing times
  - 10 mm diameter light guide
    - 1500 mW/cm^2

Single-Spectrum LED

- SmartLite Focus (Dentsply)
  - lithium-ion battery
  - fanless
  - cordless
  - 20-second curing time
  - quick-charging mode
  - 1000 mW/cm^2
  - excellent collimation

Dual-Spectrum LED

- Bluephase G2 (Ivoclar)
  - lithium-polymer battery
  - fan
  - corded or cordless
  - multiple curing times
  - 10 mm diameter fiber-optic light guide
  - soft-start polymerization available
  - low or high setting
    - 650 or 1200 mW/cm^2

Tri-Spectrum LED

- Valo (Ultradent)
  - fanless
  - corded or cordless version
  - three curing options
    - standard – 1000 mW/cm^2
    - high – 1400 mW/cm^2
    - plasma mode – 3200 mW/cm^2
  - multiple curing times

Inadequate Polymerization

- Reduced physical properties
- Decreased color stability
- Increased wear
- Increased solubility
  - leaching of unreacted monomer
  - increased toxicity

Irradiance

- Radiant Flux (power in mW) incident upon an area (cm^2)
  - surface area of the tip of the light guide

$$\text{Irradiance} = \frac{\text{mW}}{\text{cm}^2}$$

- Large tips
  - lower irradiance
- Small tips
  - higher irradiance

Radiant Exposure or Energy Density

- Irradiance over time
  - $mW/cm^2 \times sec = mJ/cm^2$
- Reciprocity
  - ↑ irradiance ↓ time
  - ↓ irradiance ↑ time

Required energy (mJ/cm2)	20,000	20,000	20,000	20,000
Irradiance (mW/cm^2)	500	1000	2000	4000
Curing time (sec)	40	20	10	5

Type of Composite

- Darker and opaque shades impede energy transmission

Shortest Exposure Time

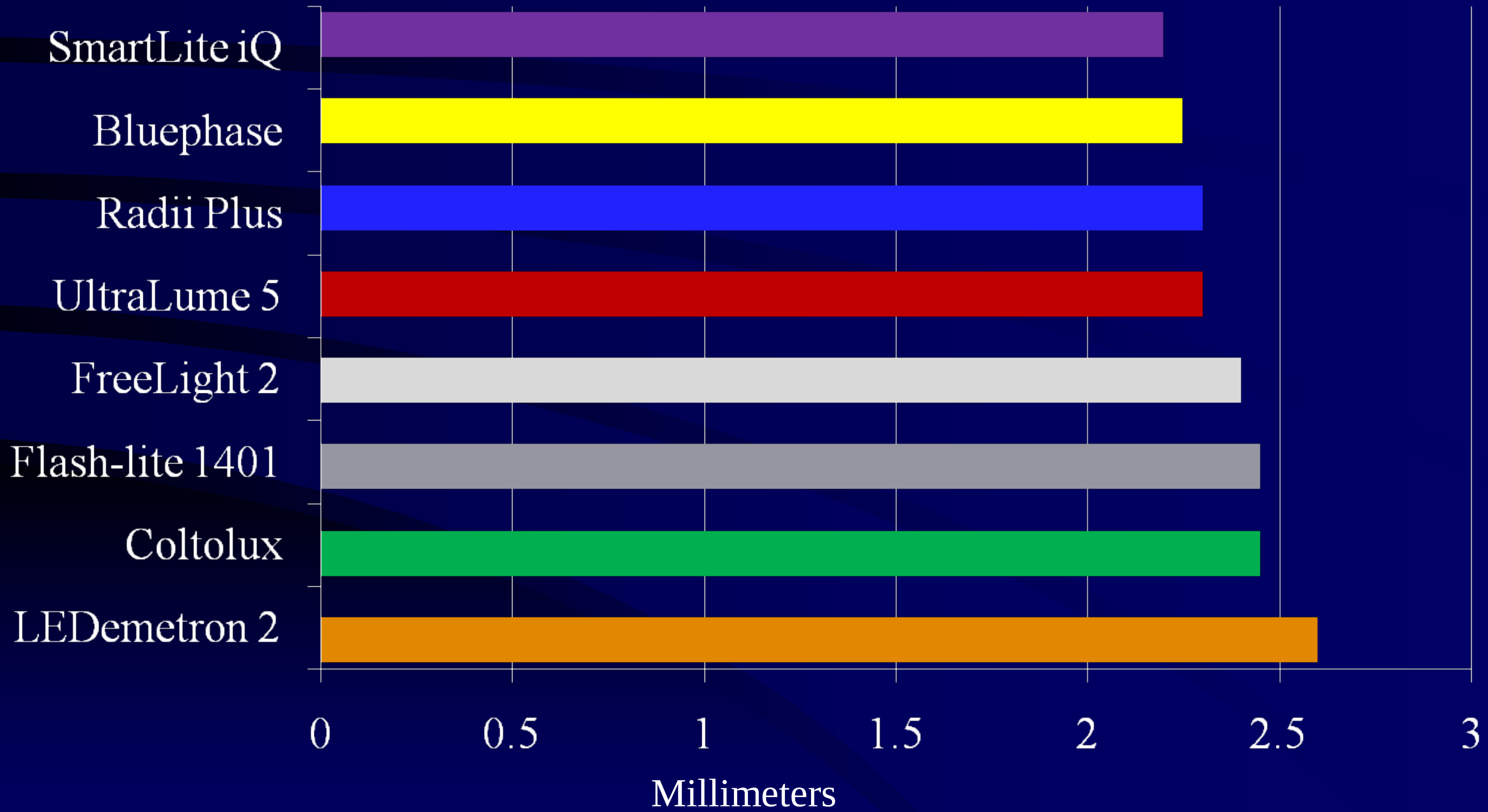
- Nine LED curing lights
  - Bluephase, Bluephase 16i, Bluephase G2, Bluephase 20i, FreeLight 2, Elipar S10, Radii plus, Mini LED Autofocus
- Two composites
  - Tetric EvoCeram, Filtek Supreme
    - various shades
- Bottom/top hardness ratios
- “10 seconds should be the minimal exposure time recommended for lighter shades under optimal circumstances”

Busemann Am J Dent 2011

Depth of Cure

20 Seconds

Herculite (Shade A2)



PPR 2008

Curing Light	Irradiance (mW/cm^2)	Percent Bottom/Maximum Knoop Hardness Ratio (St Dev)						
		Durafill VS	Esthet-X	Filtek Z250				
		A1	A1	A1	A2	A3	A3.5	A4
Demi (Kerr)	1777	40.9 (3.3) b	53.5 (2.3) ab	88.7 (1.6) a	87.1 (1.7) a	81.8 (2.7) ab	75.5 (2.5) b	
Bluephase 20i (Ivoclar)	2626	35.3 (2.1) c	47.3 (2.9) bc	80.5 (3.8) b	85.1 (3.1) a	84.2 (2.9) a	78.5 (2.4) b	
Elipar S10 (3M ESPE)	1368	39.7 (4.3) bc	61.3 (6.8) a	76.8 (6.8) b				
Fusion (DentLight)	1713	46.7 (2.2) a	43.9 (1.7) c	89.8 (4.2) a	82.7 (6.6) a	79.3 (2.5) b		
Valo (Ultradent)	2765	38.5 (1.0) bc	56.6 (5.6) a	92.0 (1.9) a	85.5 (1.6) a	81.3 (2.8) ab	84.1 (4.2) a	73.0 (1.9)

Groups with the same letter by column are not significantly different (ANOVA/Tukey; p>0.05)

Podlin, et. al. IADR 2011

Dental Offices

- 422 dental offices in 14 cities
- 915 curing lights
- 2/3 DID NOT meet manufacturer's recommended minimum energy requirement for their composite
  - output
  - curing time
  - distance
  - operator technique

Felix IADR 2015

Maintenance

- Check irradiance
  - radiometer
- Periodic visual inspection of unit
  - light guide
  - filters
  - bulb
  - battery

Hand-held Radiometers

- Numerical
  - analog
  - digital

Radiometer Recommendations

- Initial baseline irradiance
- Compare to subsequent irradiance values
  - at least monthly
  - use the same diameter tip
  - keep a log

Damage or Contamination of Light Tip

- Reduces passage of light
- Reflects light
  - increases heat build-up
  - shortens bulb life
- Remove debris
  - polishing kit
  - replace light guide as necessary

Filtek Supreme Ultra
(3M ESPE)

- Nano-composite (3M ESPE)
- Filler particles
  - filled: 78% wgt
  - nanomers
    - 0.02 – 0.07 microns
  - nanocluster
    - act as single unit
      - 0.6 – 1.4 microns

Clinical Study

- Microhybrid (Filtek Z100)
- Nanofill (Filtek Supreme)
- No significant difference in wear after 5 years
- Wear correlated with operator, size and location
- Nanofill maintained better polish

Palaniappan Dent Mater 2009, 2011

Clinical Performance

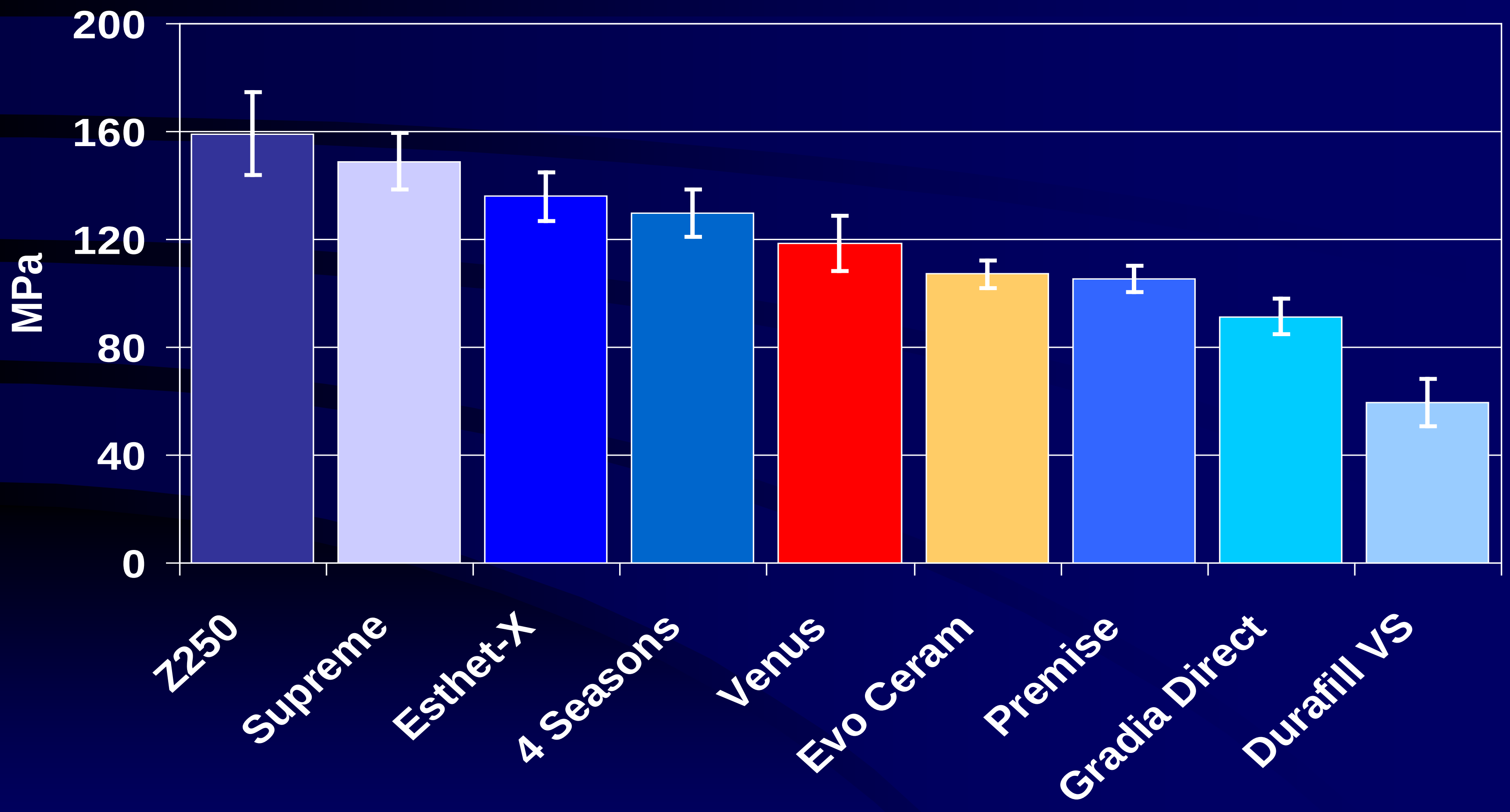
- Large differences in clinical behavior not easily demonstrated between composites
  - limited number of studies
  - limited number of composites
  - short observation times
    - typically less than 5 years
- Relationship between laboratory and clinical performance
  - only after long observation times

Clinical Study

- 22-year retrospective longitudinal study
- 362 class 1 and 2 restorations
  - P-50 (3M ESPE)
    - 70% filled
    - 1.5% annual failure rate
  - Herculite XR (Kerr)
    - 55% filled
    - 2.2% annual failure rate

Da Rosa Rodolpho Dent Mater 2011

Flexural Strength



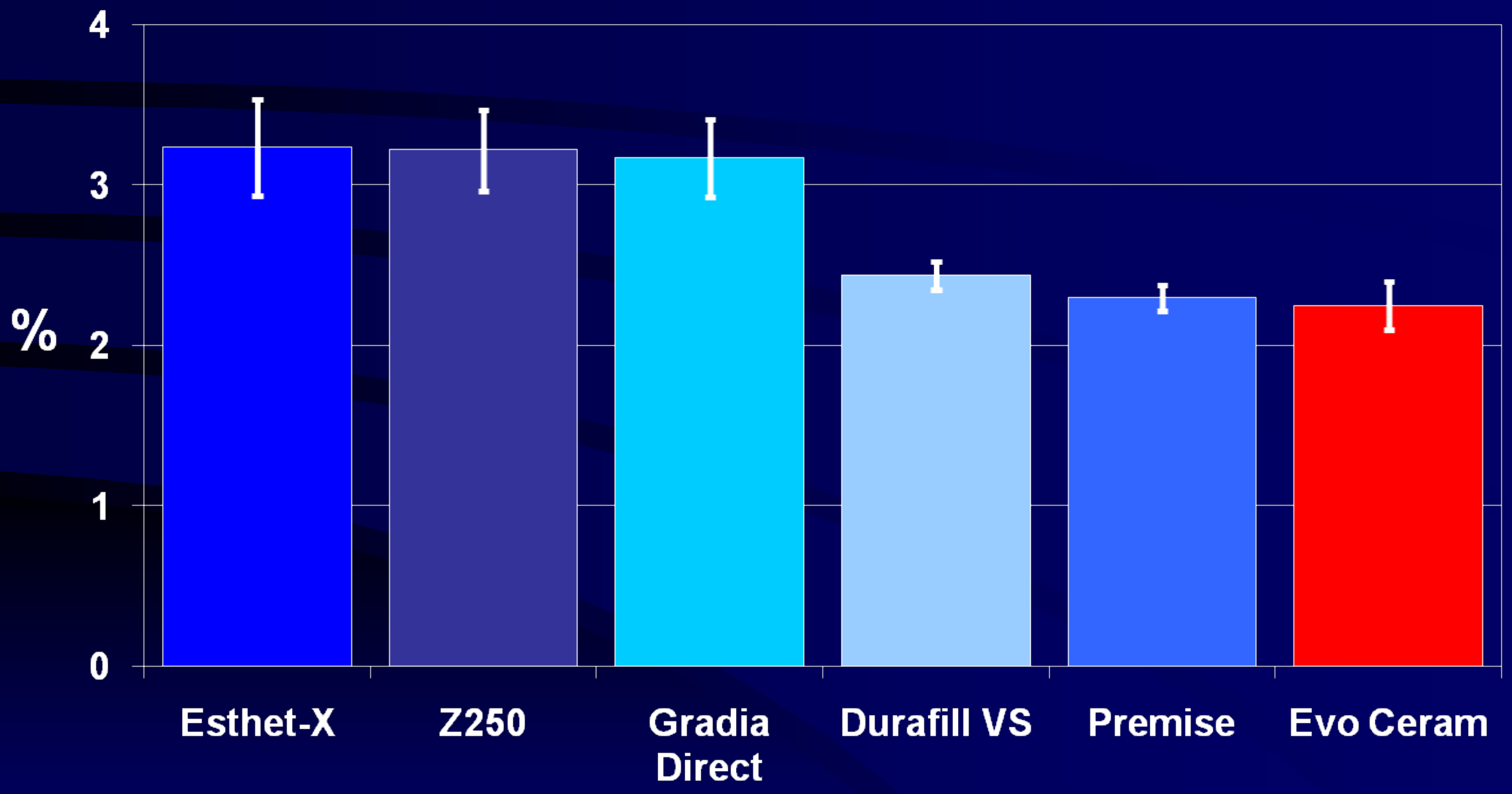
Blackham Oper Dent 2009

Overall Considerations

- Clinical variables
  - type, size, location
- Operator technique
- Socioeconomic factors
  - income, type of dental service
- Demographic factors
  - age
- Behavioral factors
  - caries prevalence

Demarco Dent Mater 2012

Polymerization Shrinkage



Blackham Oper Dent 2009

Low-Shrinking Composites

- Low-shrinking monomers
  - DX-511 dimethacrylates
    - Kalore, GC
  - dimer-acid dimethacrylates
    - N'Durance, Septodont
  - silorane
    - Filtek LS, 3M ESPE

Low-Shrinking Composites

- Filtek LS (3M ESPE)
- Silorane-based, microhybrid posterior composite
- Indications
  - Class 1 and 2
- 4 shades
  - A2, A3, B2, C2
- Dedicated adhesive system
  - two-step self-etch

Clinical Performance: 5 years

- Class 1 and 2 restorations in 25 patients
- Filtek LS / LSA adhesive
- Filtek Z250 / Scotchbond SE or XT
- Deterioration of marginal adaptation
  - – self-etch systems
- No advantage - silorane vs methacrylate
  - – low shrinkage of silorane
    - may not be advantageous

Baracco Clin Oral Invest 2016

Incremental vs. Bulk Fill

- Historically, 2 mm increments
- New flowables and restoratives
  - 4 mm or greater
- Restorative examples
  - Quixx (Dentsply)
  - Tetric Evo Ceram Bulk Fill (Ivoclar)
  - SonicFill (Kerr)
  - Filtek Bulk Fill (3M/ESPE)
- More translucent
- Additional photoinitiator
- More photoinitiator

Incremental Placement

- Reduce consequences
  - light attenuation
  - shrinkage stress

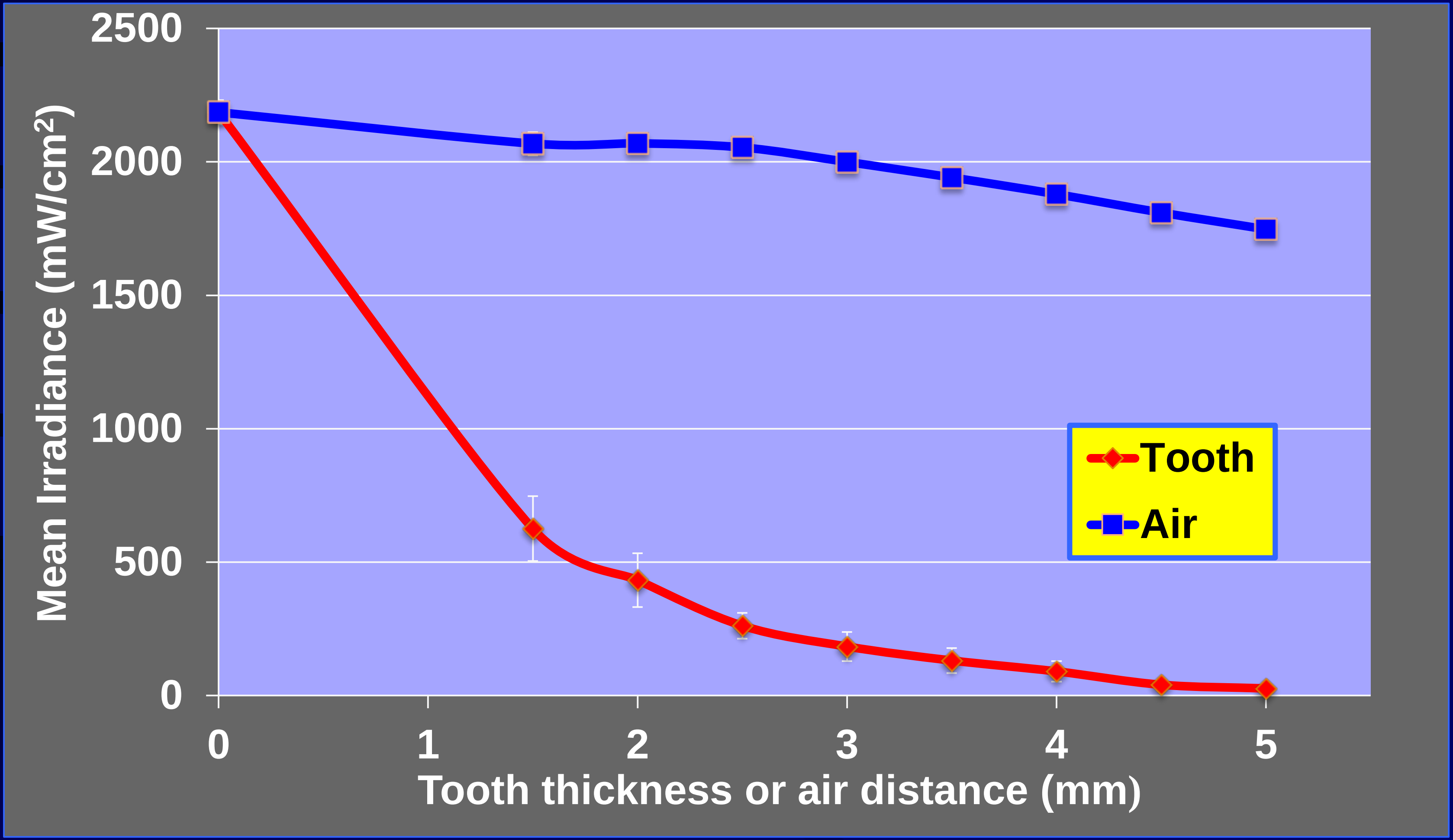
Depth of Cure

- Increment thickness
  - adequate mechanical properties
  - biocompatibility

SonicFill

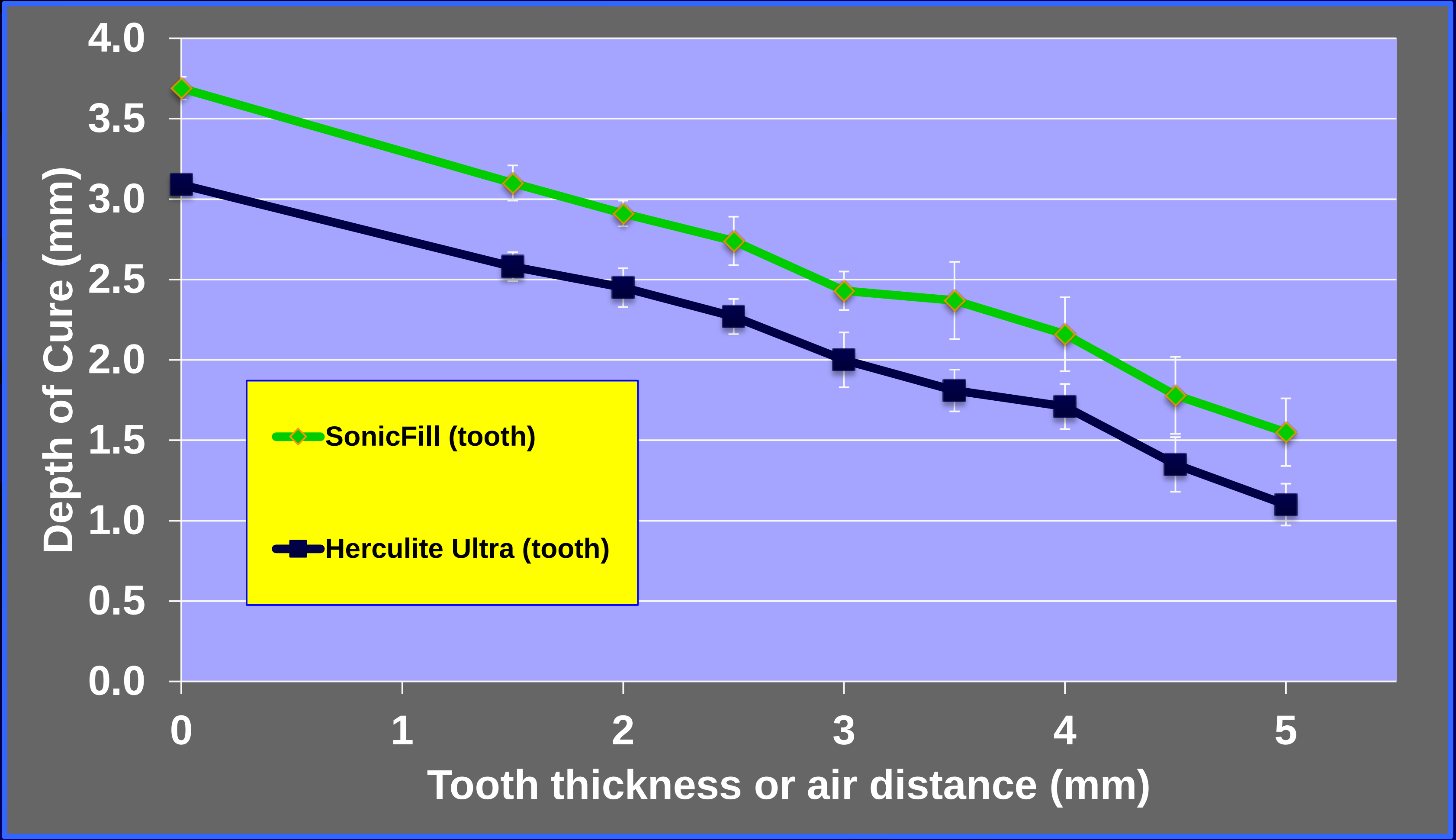
- Single step, bulk fill
- Up to 5mm
  - tri-sited cure
- Sonic activation
  - ↓viscosity
- Expensive
  - $789.99 (govt price)

Light Attenuation



Hamlin Oper Dent 2016

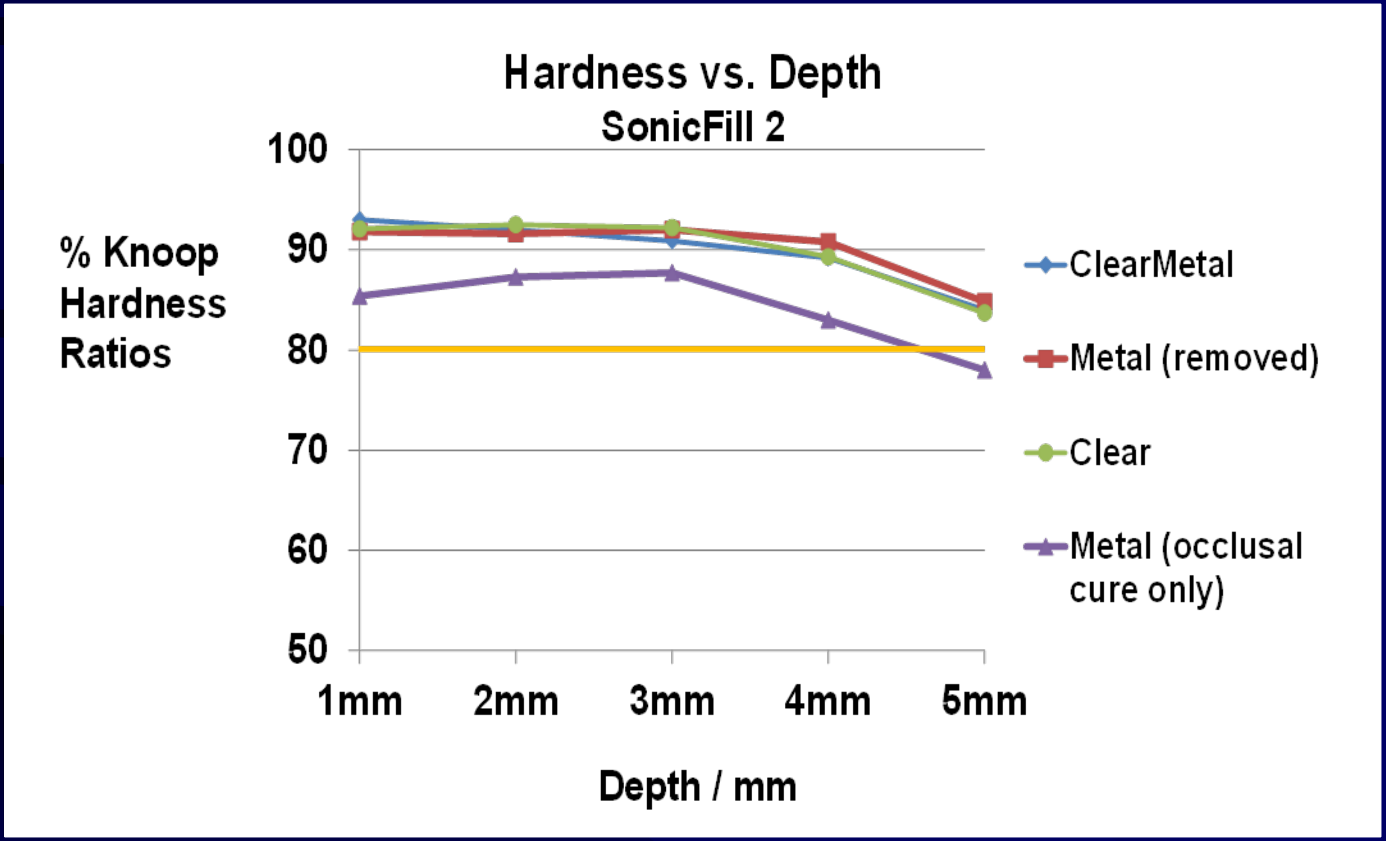
Depth of Cure



Hamlin Oper Dent 2016

Hardness vs. Depth

SonicFill 2



Nguyen Accepted for Publication

Filtek Bulk Fill (3M ESPE)

- 5 mm depth of cure
  - Class 2 preparations
    - tri-sited cure
      - » occlusal, buccal and lingual curing
- Nanocomposite
- Fragmentation monomer
  - Stress-reducing

Consensus Statement

(Light-cured Bulk-fill Composites)

- Advantages
  - may reduce placement time
  - may reduce air voids
  - may have stress-reduction monomers
- Disadvantages
  - may need more than one increment
    - measure maximum preparation depth
  - supplemental cure from buccal and lingual
  - learning curve
  - may not be as esthetic

Consensus Statement

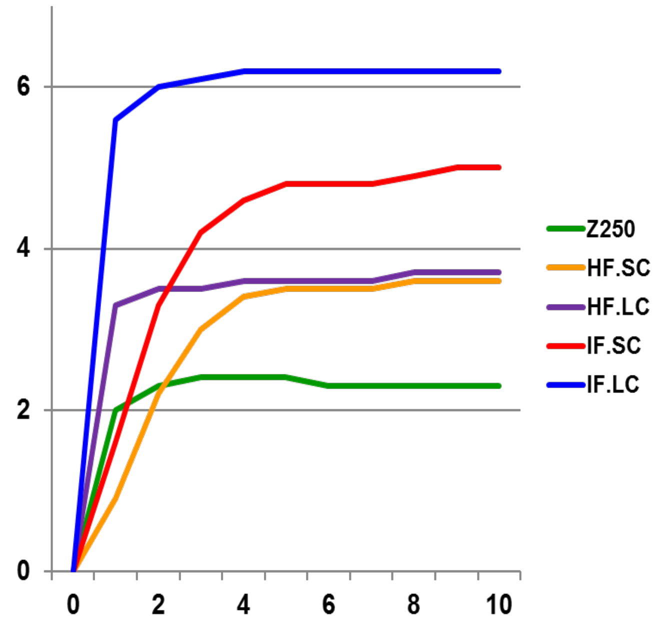
(Light-cured Bulk-fill Composites)

- Compared to incrementally placed light-cured composites
  - similar in composition
    - may be more translucent
  - should perform similarly
    - posterior, stress-bearing areas
- However, multiple-long term clinical studies are not available
- Incrementally placed – still “gold standard”

Physical Properties

Restorative Material	Physi Mea	
	Depth of Cure (mm)	**Volumetric Polymerization Shrinkage** (%)
Hyperfill Light Cured (Universal)	2.36 (0.10) b	2.9 (0.4) ab
Hyperfill Self Cured (Universal)	Full Cure	3.6 (0.7) b
Injectafil DC Light Cure (Universal)	2.06 (0.04) c	5.2 (0.5) c
Injectafil DC Self Cured (Universal)	Full Cure	3.1 (0.6) b
Filtek Z250 (A2)	3.57 (0.02) a	2.3 (0.3) a

Groups with the same letter per column are not sigı

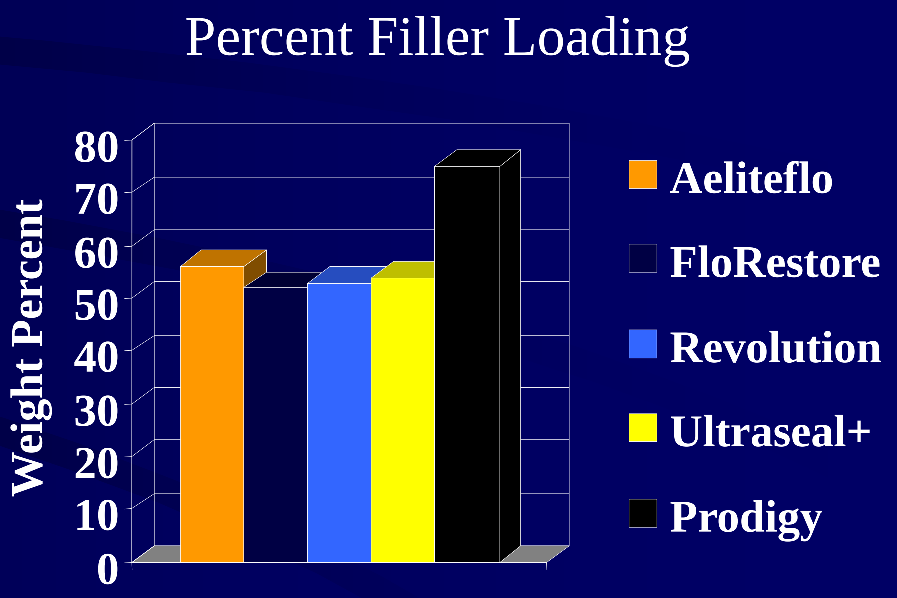


Trends

- Composite restoratives
  - better polish / esthetics
  - less shrinkage / stress
  - bulk placement

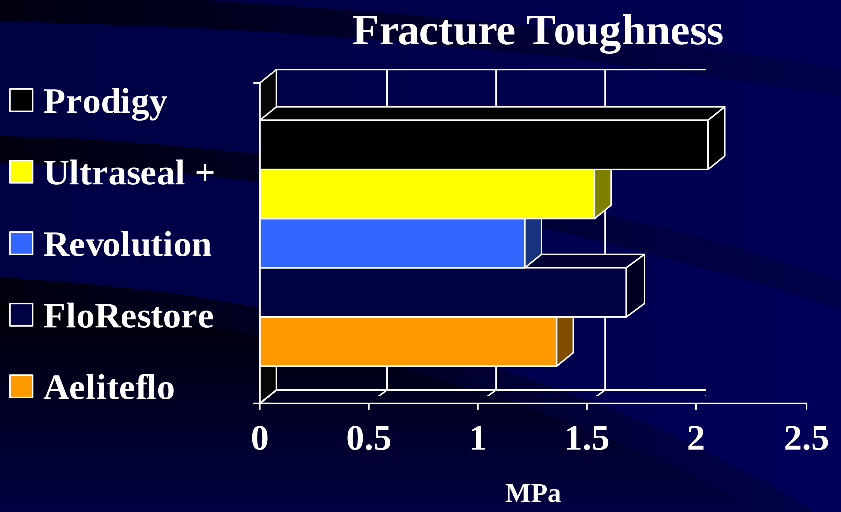
Flowable Composites

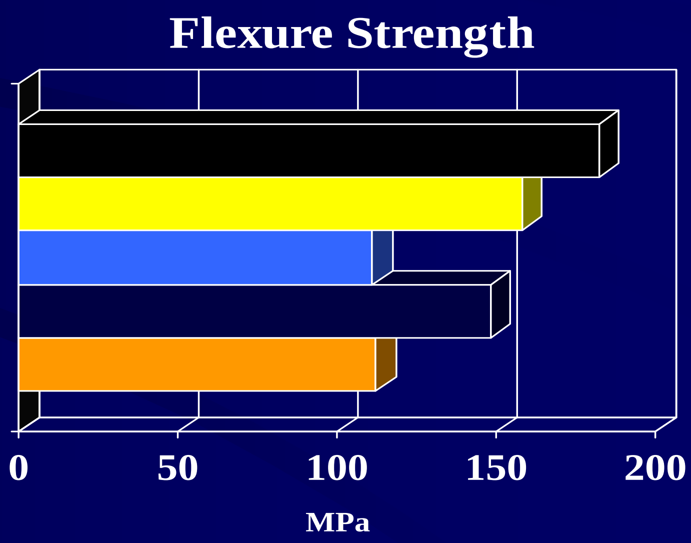
- Marketed
  - class 1, 3, 5
  - liner
- Particle size similar to hybrid composites
- Reduce viscosity
  - reduced filler content
  - surfactants added



Flowable Composites

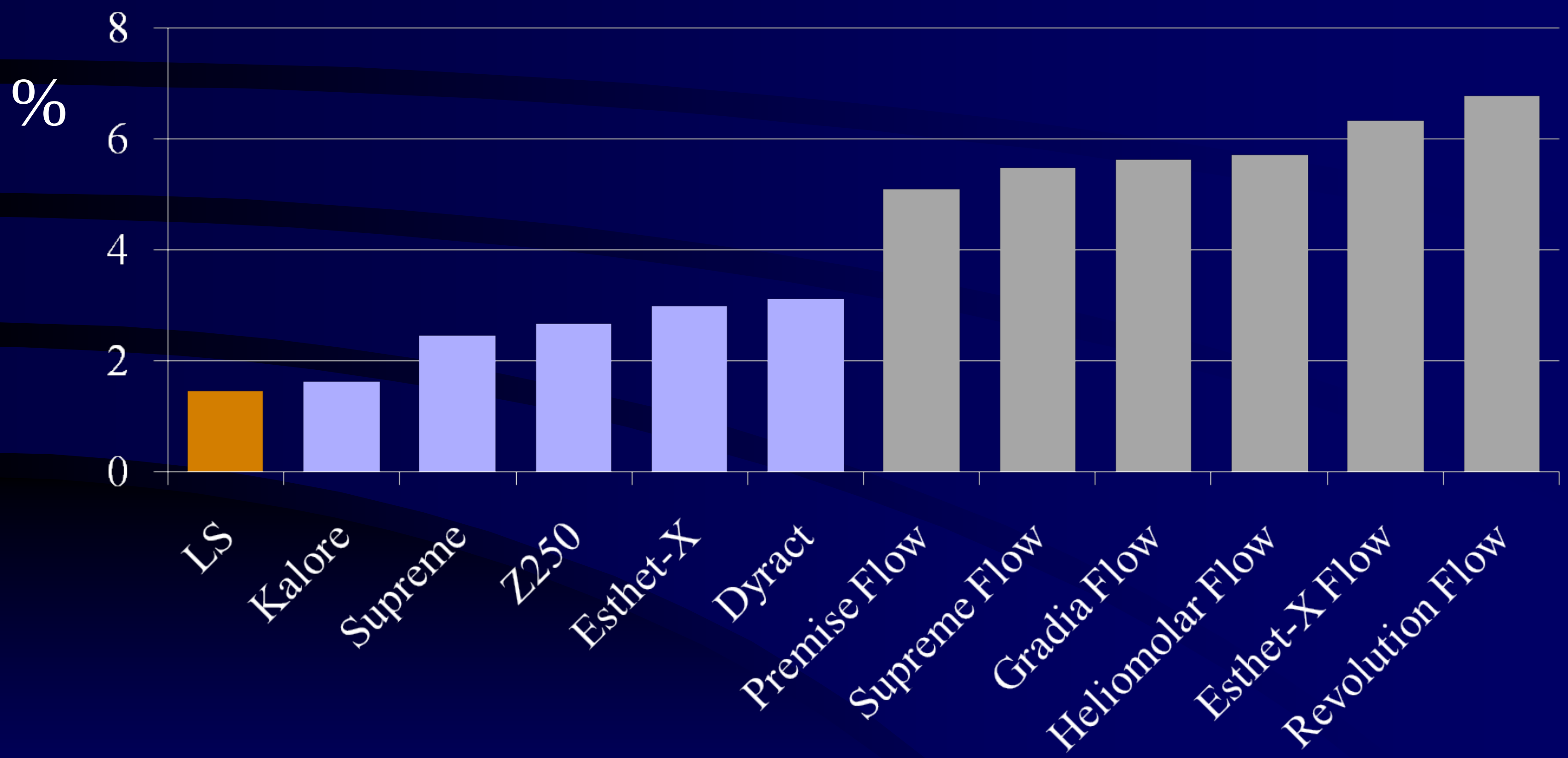
- Mechanical properties
  - inferior to hybrids





Bayne JADA 1998

Polymerization Shrinkage



Napoles IADR 2008
Lien Dent Mater 2010

Flowable as a Liner

- 2-yr clinical studies
  - Class 2 composite resin restorations
    - with and without flowable liner
    - no difference
  - Class 1 composite resin restorations
    - with and without flowable liner
    - no difference
- 7-yr clinical study
  - Class 2 composite restorations
    - with and without flowable liner
    - no difference

Stefanski Clin Oral Investig 2012
Ernst Clin Oral Investig 2003
Efes Adhes Dent 2006
Van Dijken Dent Mater 2010

Flowable Composites

- Clinical applications
  - small micropreps
    - PRRs
  - small Class 5
  - repair
    - provisional
    - restoration margins
    - crown margins
  - liners??

Clinical Study
(Class 1 Restorations)

- Flowable vs. Conventional Nanofill
- 98 Class 1 restorations in 49 patients
- Filtek Supreme Ultra Flowable
  - filled 65% wgt / 46% vol
- Filtek Supreme Ultra Restorative
  - Filled 72% wgt / 56% vol
- No significant difference at two years

Lawson Oper Dent 2015

Clinical Study

(Class 2 Restorations)

- Flowable vs. Conventional Nanohybrid
- 78 Class 2 restorations in 40 patients
- GrandioSO Heavy Flow (VOCO)
  - filled 83% wgt / 68% vol
- GrandioSO Restorative (VOCO)
  - Filled 89% wgt / 73% vol
- No significant difference at two years

Torres J Dent 2014

Bulk-Fill Flowables

- Placed in bulk
  - up to 4 mm
- Covered with restorative composite
  - SureFil SDR (Dentsply)
  - Grandio Flow (Voco)
  - Venus Bulk Fill (Kulzer)
  - Filtek Bulk Fill (3M ESPE)

Bulk-Fill Flowables

- May present some stress-reduction properties
  - Moorty J Dent 2012
  - Van Ende Dent Mater 2013
  - El-Damanhoury H Oper Dent 2014
- Must be covered with a restorative composite
  - Ilie Oper Dent 2013
- Depth of cure
  - product dependent
- May be very translucent
  - Lasila J Dent Res 2012
- Lack of clinical studies

Clinical Study

(3-years)

- 38 Class II and 15 Class I
  - paired restorations
- Nano-hybrid composite
  - Ceram X (Dentsply)
  - incremental
  - 1.3% annual failure rate
- Bulk-fill flowable/hybrid composite
  - Surefil SDR (Dentsply)
  - up to 4mm
  - covered with 2-mm hybrid composite
  - 0% annual failure rate

Van Dijken Dent Mater 2014

Trends

- Flowable composites
  - less shrinkage stress
  - greater strength
  - bulk placement
  - self-adhesive

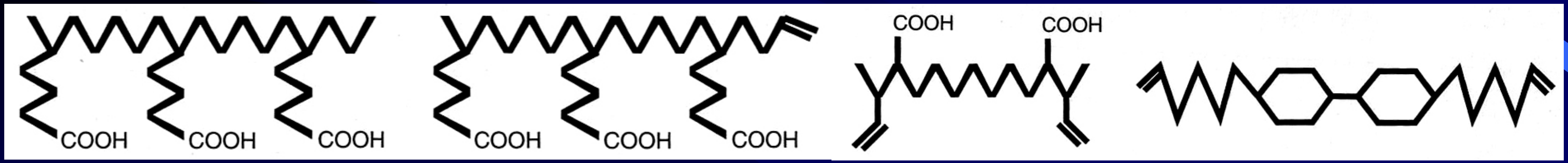
Continuum

Glass Ionomers

Resin-Modified G.I.

Compomers

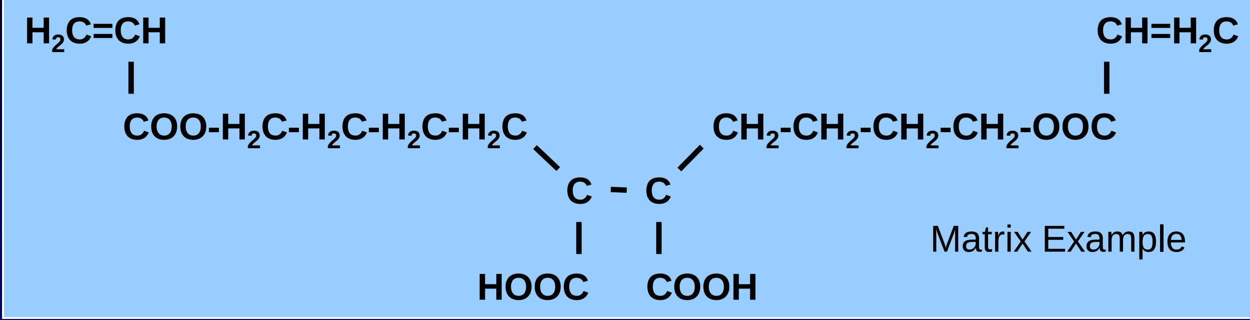
Composites



Compomers

*Comp*osite and Glass-ion*omer*

- Polyacid-modified composite resin
- Similar chemistry to composite resins
  - Bis-GMA, silicate glass, initiators
- Additionally
  - matrix
    - dimethacrylate monomer
    - carboxylic groups
  - filler
    - ion-leachable glass
- No water



Matrix Example

Setting reaction

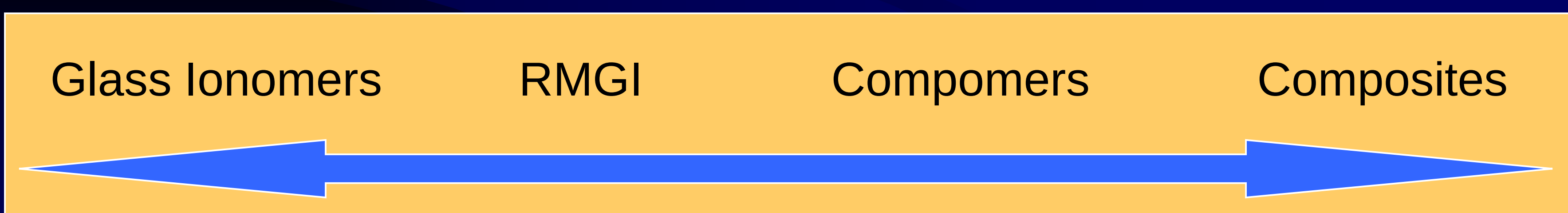
- Free-radical polymerization reaction
  - similar to resin composites
- No chemical bond to tooth structure
- Low levels of fluoride release
- Delayed acid-base reaction
  - water from tubules, absorption

Compomers in Dentistry

- Direct restorations
  - restoratives
  - flowables
  - sealants
- Cements

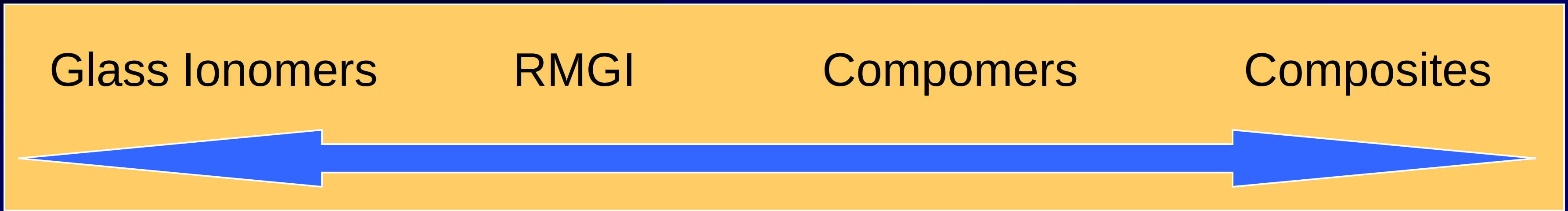
Advantages

- Easy to place and polish
- Some fluoride release
- More esthetic than glass ionomer
- Better mechanical properties than glass ionomer



Disadvantages

- Inferior mechanical properties compared to composite
  - – decreased fracture toughness
    - Yap Oper Dent 2004
- Less fluoride release than glass ionomer
  - – minimal recharge
- Less color stability compared to composites
  - – due to water absorption



Clinical Study

- Class 2 restorations
  - TPH composite (Dentsply)
  - Dyract compomer (Dentsply)
- 3 years
  - Compomer
    - greater occlusal wear
    - greater marginal degradation

Wucker Am J Dent 2002

Giomers

- Resin-based restoratives
- Indications
  - Class I – Class V
- Pre-reacted glass-ionomer particles (PRG)
  - fillers from conventional GI reaction
- Free-radical polymerization reaction
  - similar to light-activated resin composites
- No chemical bond to tooth structure
- More research needed
- Example
  - Beautifil 2 (Shofu)
    - surface reaction type

Clinical Study

- Class I and II study
  - no control group
  - 13 years
    - 25/41 acceptable
      - 2 carious, 2 missing, 10 crowned
        2 replaced
    - increased marginal staining
      - Gordan JADA 2014

Ormocers

(ORganically MOdified CERamic)

- Admira Fusion (VOCO)
- “Pure Silicate Technology”
  - fillers and resin matrix based purely on silicon oxide
- Reportedly the lowest polymerization shrinkage (1.25 %) and shrinkage stress
  - in comparison to all conventional restorative composites

Ormocers

(ORganically MOdified CERamic)

- Admira Fusion (VOCO)
- Nanohybrid
- Like a “barbed wire”
  - fully polymerized
    - wire – polysiloxane backbone
    - barb – methacrylate groups
    - fillers – silica glass
- Contains no classic monomers
  - like bis-GMa

Clinical Studies

- 5-yr clinical study
  - 128 class 2 restorations
    - two ormocers - Admira (Voco), Definite (Degussa)
    - one bis-GMA - Tetric-Ceram (Ivoclar Vivadent)
  - no difference between the groups
- 3-yr clinical study
  - 160 class 1 and 2 restorations
    - one ormocer – Admira (Voco)
    - two methacrylates – Filtek Supreme (3M), Ceram-X (Dentsply)
  - no difference between the groups

Bottenberg J Dent 2009
Mahmood Oper Dent 2014

Bioactive Dental Materials

- Biointeractive
  - conventional GI and RMGI
- Bioactive
  - forms apatite-like material on its surface
    - calcium silicates
    - calcium aluminates
  - acid/base reaction
    - elevate local pH

Jefferies J Esthet Rest Dent 2014

Bioactive Dental Materials

- ProRoot MTA (Dentsply)
  - pulp capping
- Biodentin (Septodont)
  - liner/base
- Ceramir C&B (Doxa Dental)
  - luting agent
- EndoSequence (Brasseler)
  - root canal sealer
- Activa (Pulpdent)
  - restorative

Jefferies J Esthet Rest Dent 2014

BioActive Resin
(Pulpdent)

- “Resin-modified glass ionomer bioactive ionic resin-based composite”
  - patented bioactive ionic resin
  - patented rubberized resin
  - bioactive glass ionomer
- Tri-cure
- “Smart” bioactive material
  - Reacts to pH - releases, recharges calcium, phosphate and fluoride

Biocompatibility of Composites

- Tolerated by pulp
  - with good seal
- Rare allergic reactions
  - HEMA
- Cytotoxicity
  - short lived
    - not a chronic source
- Degree of cure important
  - decrease free monomer
    - only 8% of unreacted C=C elutable

Bisphenol A (BPA)
(Resin-based Dental Materials)

- By-product of bis-GMA or bis-DMA
  - manufacturing process
- Salivary enzymatic breakdown of bis-DMA
- Most dental materials have bis-GMA
- Detected in saliva in minute amounts
  - up to 3 hours
- Absorption and health significance unknown
- One-time exposure
  - 200 times lower than daily EPA threshold
    - far less exposure than other consumer items

Fleisch Pediatrics 2010

BPA Urinary Concentrations

- 91 children/adolescents
- Z100 composite restorations
  - Bis-GMA-based material
- Urine analyzed
  - pre-op, 1 day, 14 days, 6 months
- Transient increase in BPA concentration
  - no longer detectable at 14 days or 6 months

Maserejian JADA 2016

ADA Position

- Human exposure
  - short term
  - low level
  - unwarranted concern
  - “most residual BPA is probably locked inside the polymer matrix after polymerization”

Amalgam vs. Composite

- Average lifetime of composite restoration
  - 6 – 7 years
    - NIDCR
- Composite failure due to caries
  - typically higher than for amalgam
- “…preponderance of clinical evidence demonstrates the overall enhanced longevity of amalgam restorations…”

Ferracane Dent Mater 2015

Systematic Review

Cochrane Summaries
(Oct 2013)

- Seven published studies reviewed
  - 2 met criteria
    - 3265 composites / 1935 amalgam restorations
- "Results suggest that tooth-colored (composite) fillings are almost twice as likely to fail compared with amalgam fillings when used for filling permanent teeth at the back of the mouth"

Systematic Review

- 8 studies from 1992 – 2013 met criteria
- Composite less longevity than amalgam
  - 46% higher probability of failure
  - secondary caries significantly higher in composites
    - critical factors
      - adhesive technique, enamel vs. dentin
  - no difference based on fracture

Moraschini J Dent 2015

Bonding Amaglam

Five-Year Clinical Study

- Conventional restorations
  - 39 Class I
  - 327 Class II
- Five bonding agents
  - Scotchbond 2, Panavia EX, Amalgabond, Amalgabond +, Geristore
  - Copal varnish
- No difference

Smales Oper Dent 2000

Bonding Amaglam

Five-Year Clinical Study

- Conventional restorations
  - 75 bonded
  - 62 nonbonded
- No difference

Mach JADA 2002

Review of Clinical Studies

- Cochrane Collaboration Study
  - randomized controlled clinical trials
    - paired tooth or split mouth design
    - Class 1, 2 or 5 restorations
    - minimum 2 years
      - one fully qualified
- No difference in amalgam survival or post-op sensitivity
  - restoration adhesively bonded or not
- “Lack of evidence of additional benefit of adhesively bonding amalgam in comparison with non-bonded amalgam.”
- “It is imperative that clinicians are mindful of the additional costs that may be incurred.”

Recommendations for Use

Mahler 2000

- “ . . .no significant difference between post-operative sensitivity . . . no significant difference in marginal integrity . . .
- …the merit of using adhesive bonding agents for traditional Class I and Class II amalgam restorations has not been demonstrated”

Six-Year Clinical Evaluation

Summitt 2004

- Complex amalgam restorations
- Rubber dam isolation
- Pin-retained group (28)
  - TMS pins, Minim and Minikin
  - Copalite
- Bonded group (32)
  - Amalgambond Plus w/ HPA powder
- Tytin amalgam

At six years, resin-bonded complex amalgam restorations were functioning as well as pin-retained restorations.

Amalgam Bonding Materials

- Most popular material
  - Amalgambond Plus
    - three-step, etch and rinse
      - conditioner (activator)
        - » 10% citric acid, 3% ferric chloride
      - primer
        - » 4-META, HEMA
      - adhesive (base and catalyst)
        - » dimethacrylate, chemical initiators
      - powder
        - » polymethylmethacrylate

Recommendations for Use

- Additional retention desired
- Large restorations replacing a cusp
- Reinforcement of remaining tooth structure
- Interim treatment of incomplete tooth fracture

Summitt JADA 2001

Amalgam Biocompatibility

- Half-billion restorations per year
  - 75 tons of mercury
- Mercury vapor released
  - chewing and brushing
    - Berglund J Dent Res 1990
  - removal of amalgam
    - reduced 90% with high-volume evacuation
      - Pohl Acta Odontol Scand 1995
- Difficult to determine vapor levels accurately
    - Olsson J Dent Res 1992

Mercury Dose from Amalgam

- Average daily dose from 8 – 10 amalgam surfaces
  - 1-2 ug per day
  - well below threshold levels
- Threshold urine mercury levels
  - subtle, pre-clinical effects
    - 30 ug per day
  - considered dangerous
    - 82 ug per day

Olsson J Dent Res 1995
Mackert Crit Rev Oral Biol Med 1997 Berdouses J Dent Res 1995

Exposure to Mercury

- Food
  - fish, grain
- Air, water
  - naturally occurring
- Commercial products
  - antiseptics
  - ointments
  - thermometers
- Occupational
  - dentistry
  - factory workers

Forms of Mercury

- Organic
- Inorganic
- Elemental

Biologic Activity of Mercury

- Binds to protein sulfhydryl groups
  - loses structure and function
- No carcinogenicity
- Teratogenicity
  - potential to cause birth defects in developing fetus

Elemental Mercury

- Elemental (liquid) mercury
  - not as great a health hazard risk as mercury vapor
  - skin exposure
    - contact dermatitis
      - very rare
  - gloves
    - provide adequate skin protection

Elemental Mercury

- Un-ionized mercury
- High vapor pressure
  - significant to dentistry
- Absorption
  - readily from lungs
  - poorly from GI and skin
    - < 0.1%
    - not toxic when swallowed

Concerns with Amalgam

- Hypersensitivity
- Multiple sclerosis
- Alzheimer’s disease
- Renal toxicity
- Reduced immunocompetence
- Amalgam illness
- Dental occupational exposure
- Amalgam waste

Hypersensitivity

- Type IV or cell-mediated immune response
- Contact dermatitis
- Lichenoid lesions adjacent to amalgam
- Most reactions subside
  - amalgam removal usually not necessary
- True allergy is rare

Major Health Organizations

- Alzheimer's Association

  "…no connection between Alzheimer's and mercury-containing dental fillings…"

- National MS Society

  "There is no scientific evidence to connect the development of MS or other neurological diseases with dental fillings containing mercury."

- Food and Drug Administration (FDA)

  "…no valid scientific evidence has ever shown that amalgams cause harm to patients with dental restorations."

- American Dental Association

  "Dental amalgam (silver filling) is considered a safe, affordable and durable material…"

FDA Ruling

While elemental mercury has been associated with adverse health effects at high exposures, the levels released by dental amalgam fillings are not high enough to cause harm in patients.

July 28, 2009

Amalgam Restrictions

- Typically to reduce the amount and sources of mercury by various countries
  - in the environment
  - exposure to children and pregnant women
- Examples
  - Belgium, Denmark, Finland, Sweden

Risk vs. Benefit Relationship

- Benefits and detriments to the use of any material
- Unbalanced risk assessments may lead to the waste of limited health resources
  - deny public access to beneficial therapies

Dental Economics

- Ban on amalgam
  - Increase average price of restoration
    - from $278 to $330
      - 18.7%
  - Decrease number of restorations placed
    - 15 million fewer restorations
  - More untreated caries
    - underprivileged populations

Minamata Convention

- Global agreement
  - protect human health
    - anthropogenic emissions
    - releases of mercury
  - range of measures
    - mining
    - mercury-added products
    - manufacturing processes
  - phase down the use of amalgam

Minamata Convention

- Over 120 countries
- Obama Administration
  – approved
    - 6 November 2013

- "The United States has already taken significant steps to reduce the amount of mercury we generate and release to the environment, and can implement Convention obligations under existing legislative and regulatory authority. The Minamata Convention complements domestic measures by addressing the transnational nature of the problem."

Publically Owned Treatment Works

- 100,000 dental offices
  - use or remove amalgam in the United States
  - almost all send wastewater to POTWs
  - 50% of mercury entering plants
    - approximately 5.1 tons of mercury annually
      - most subsequently released to the environment
        - » through the incineration, landfilling, or land application of sludge or through surface water discharge
  - but < 1% of mercury released into the environment from man-made sources
    - comes from dentistry

EPA 2016

Amalgam Separators

- Reduce amount of amalgam discharged into sewer system from dental vacuum systems
  - > 95% of amalgam
- Removes amalgam
  - sedimentation
  - filtration
  - ion exchange

EPA Ruling

Amalgam Separators

- New national requirement
  - final Rule – 15 Dec 2016
  - a federal standard
  - date of compliance
    - end of 2019
- Average annual cost
  - $800 per dental office

EPA 2016

EPA Ruling
Amalgam Separators

- Exemptions
  - – Mobile dental units
  - – Dentists who do not place amalgam
    - only remove in unplanned situations
  - – Dentists who practice
    - Oral pathology
    - Radiology
    - Oral surgery
    - Orthodontists
    - Periodontists
    - Prosthodontists

EPA 2016

Amalgam Waste

- Non-contact amalgam
  - store in sealed container
- Contact amalgam (traps)
  - disinfect and dry
    - non-chlorine disinfectant
  - combine with non-contact amalgam
- Used amalgam capsules
  - recap, if possible
  - store in sealed container

Summary

- Dental amalgam
  - releases minute amounts of elemental mercury
    - no evidence of systemic health problems
      - limited cases of allergy
- Mercury absorbed from many sources
  - no demonstration of clinical effects from additional burden from amalgam

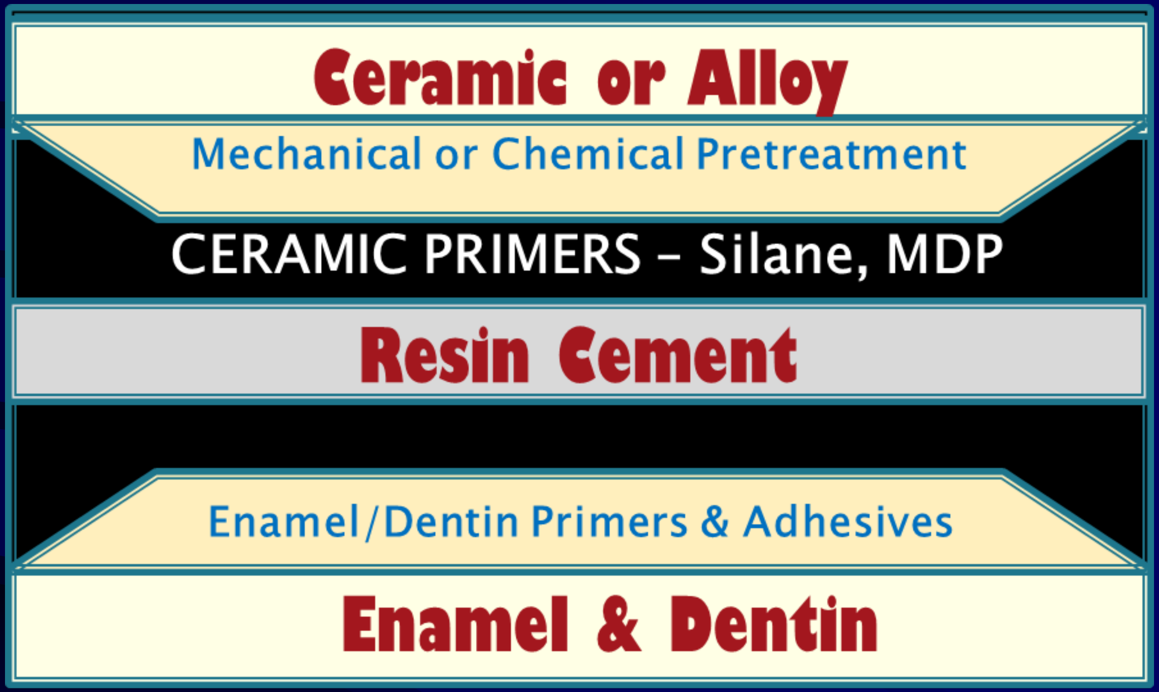
Summary

- No cure or health benefit from amalgam removal
- Dentists must inform patients
  - risks and benefits of restorative materials
- Amalgam will eventually be replaced by composite and other materials
  - esthetics
  - environment

Alternative Materials

- Typically higher cost and/or greater technique sensitivity
  - composite resin
  - glass ionomer
  - ceramic
  - metal alloys

Bonding Interface



Slide from Col Jessup

Cementation

(silica, glass-ceramics)

- Bonding
  - etch
    - hydrofluoric acid
      - e.g., Ceramic Etching Gel (Ivoclar)
  - silane
    - e.g., Bis-Silane (Bisco)
  - resin cement
    - resin cement
      - e.g., NX3, Kerr

Hydrofluoric-Acid Etch

- Etches silica dioxide glass phase
  - leaves crystalline phase
- Micromechanical retention
  - irregular, retentive surface
- Etching time
  - type of ceramic
  - concentration of HF acid
- Exposes hydroxyl (silanol, Si-OH)
  - reacts with silanol (Si-OH) group of hydrolyzed silane

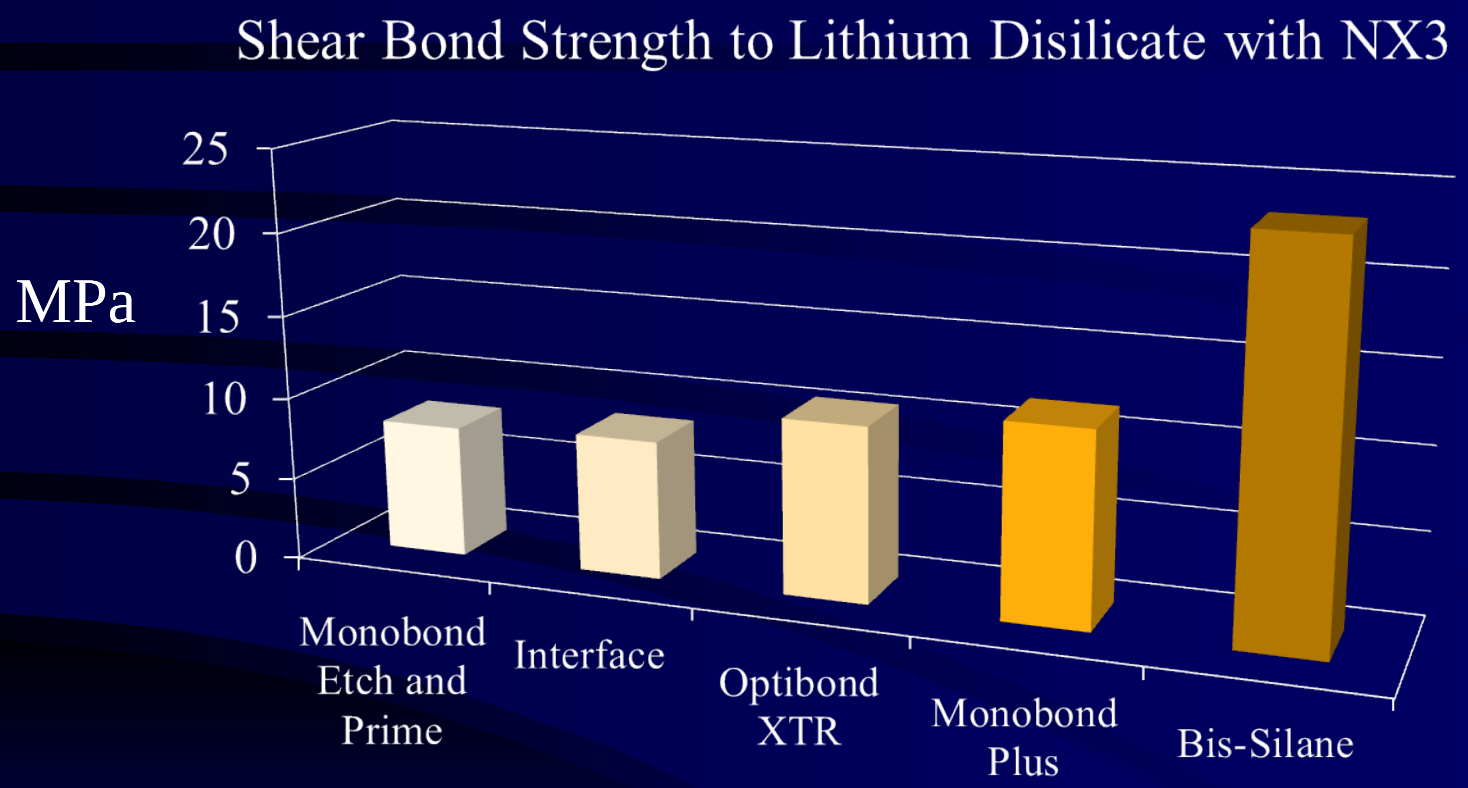
Silane Coupling Agent

- Two types
  - two-component nonhydrolyzed
    - mix before use
  - one-component prehydrolyzed
    - multi-use bottle
      - prone to degradation
        - » refrigerate

Silane Coupling Agent

- Bifunctional molecule
  - covalent bond to silica in ceramic
    - silanol (Si-OH) group of silane
    - silanol (Si-OH) group of silica
  - covalent bond to methacrylate in resin
    - carbon double bonds
      - free-radical polymerization

Universal Primers



Swank Accepted for Publication

Salivary Contamination

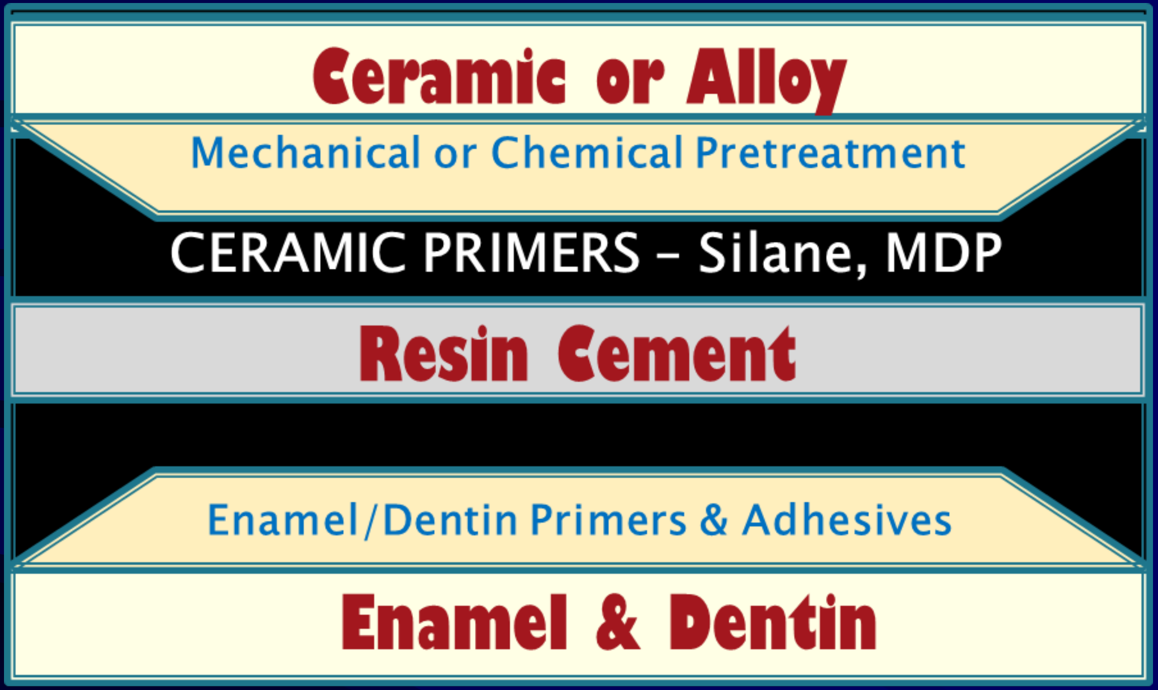
- Shear Bond Strength
- Lithium disilicate
    - e.max CAD
- Resin Cement
    - NX 3

Groups	Surface Treatment	Bond Strength MPa (st dev)
1	HF acid, rinse/dry, saliva, rinse/dry, Ivoclean, rinse/dry, silane, cement	30.1 (6.0) a
2 control	HF acid, rinse/dry, silane, cement	29.7 (5.9) a
3	Saliva, rinse/dry, HF acid, rinse/dry, silane, cement	28.7 (6.2) a
4	HF acid, rinse/dry, saliva, rinse/dry, HF acid, rinse/dry, silane, cement	25.4 (8.7) ab
5	HF acid, rinse/dry, saliva, rinse/dry, phosphoric acid, rinse/dry, silane, cement	25.0 (8.5) ab
6	HF acid, rinse/dry, silane, saliva, rinse/dry, phosphoric acid, rinse/dry, silane, cement	24.7 (7.3) ab
7	HF acid, rinse/dry, silane, saliva, rinse/dry, Ivoclean, rinse/dry, silane, cement	22.1 (9.5) ab
8	HF acid, rinse/dry, silane, saliva, rinse/dry, silane, cement	18.3 (10.2) b
9	HF acid, rinse/dry, saliva, rinse/dry, silane, cement	17.6 (8.4) b
10	HF acid, rinse/dry, saliva, silane, cement	7.8 (2.5) c

Groups with the same letter are not significantly different ($p>0.05$)

Alfaro Gen Dent 2016

Bonding Interface



Slide from Col Jessup

Adhesive Classifications

- **Adhesives**
  - **Etch & Rinse**
    - **Three-Step** etch, prime, bond
    - **Two-Step** etch, (prime & bond)
  - **Self-Etch**
    - **Two-Step** (etch & prime), bond
    - **One-Step** (etch & prime & bond)

Simplified

Simplified

Breschi in Summitt Fund Oper Dent 2013

Survival of Ceramic Inlay/Onlay Restorations

Practice-Based Research Network

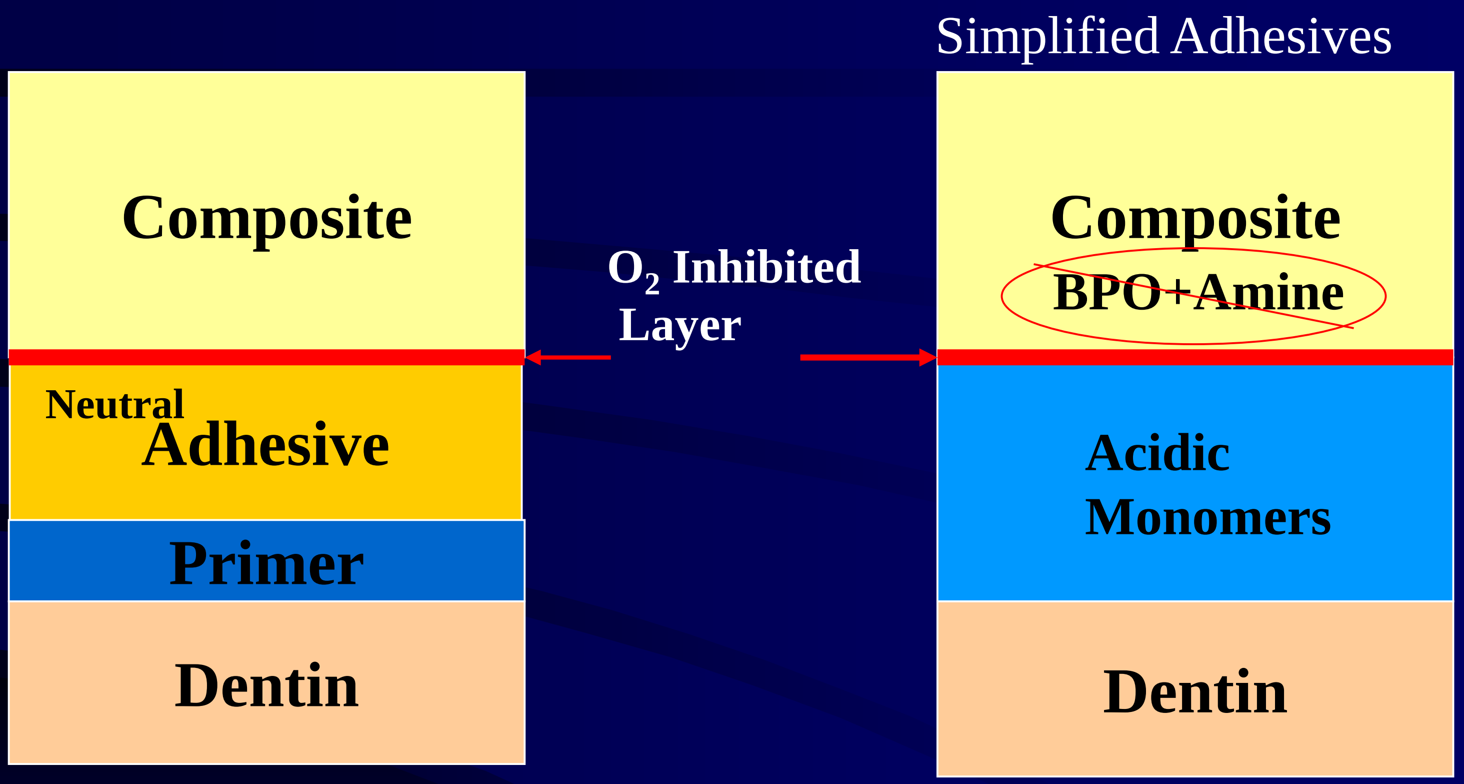
- 3-year mean observation time
  - maximum 15 year
- 5791 ceramic inlay/onlays
  - 167 dentists & 5523 patients
    - 1994 - 2014
- Simplified bonding agents
  - 142% greater failure rate compared to
- Non-simplified bonding agents
  - “…hydrophobic layer of gold-standard adhesives increases the stability of the bonds to dental tissues.”

Collares Dent Mater 2016

Incompatibilities

- Self-cure composites with simplified adhesives
    - two-step etch & rinse
    - one-step self-etch
- Acidic monomers react with basic catalyst of overlying composite
- Adhesive permeability leads to superficial water blisters via water trees

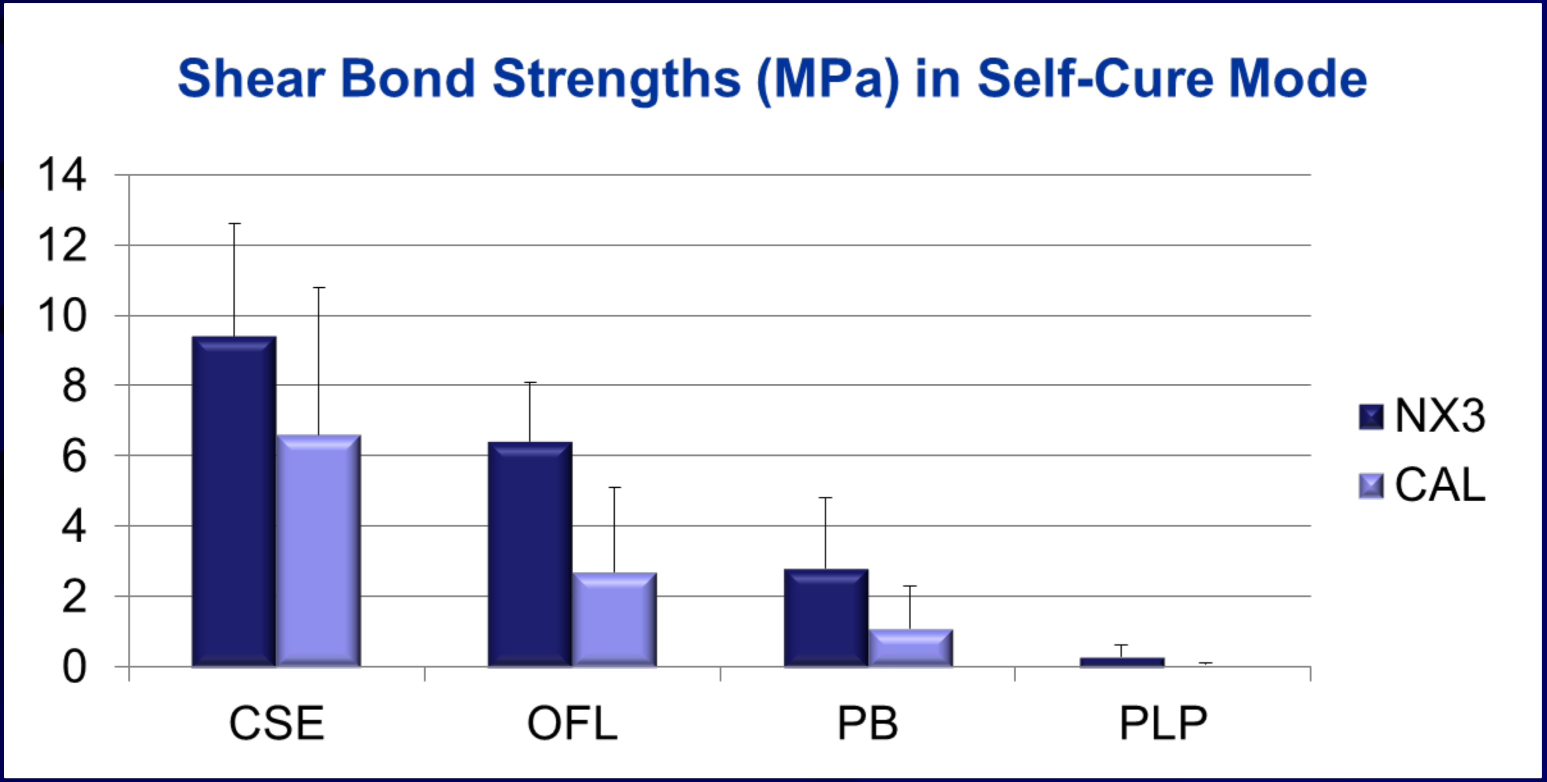
Adverse Acid-Base Reaction



Three-step Etch & Rinse
Two-step Self-Etch

Two-step Etch & Rinse
One-step Self-Etch

Laboratory Study

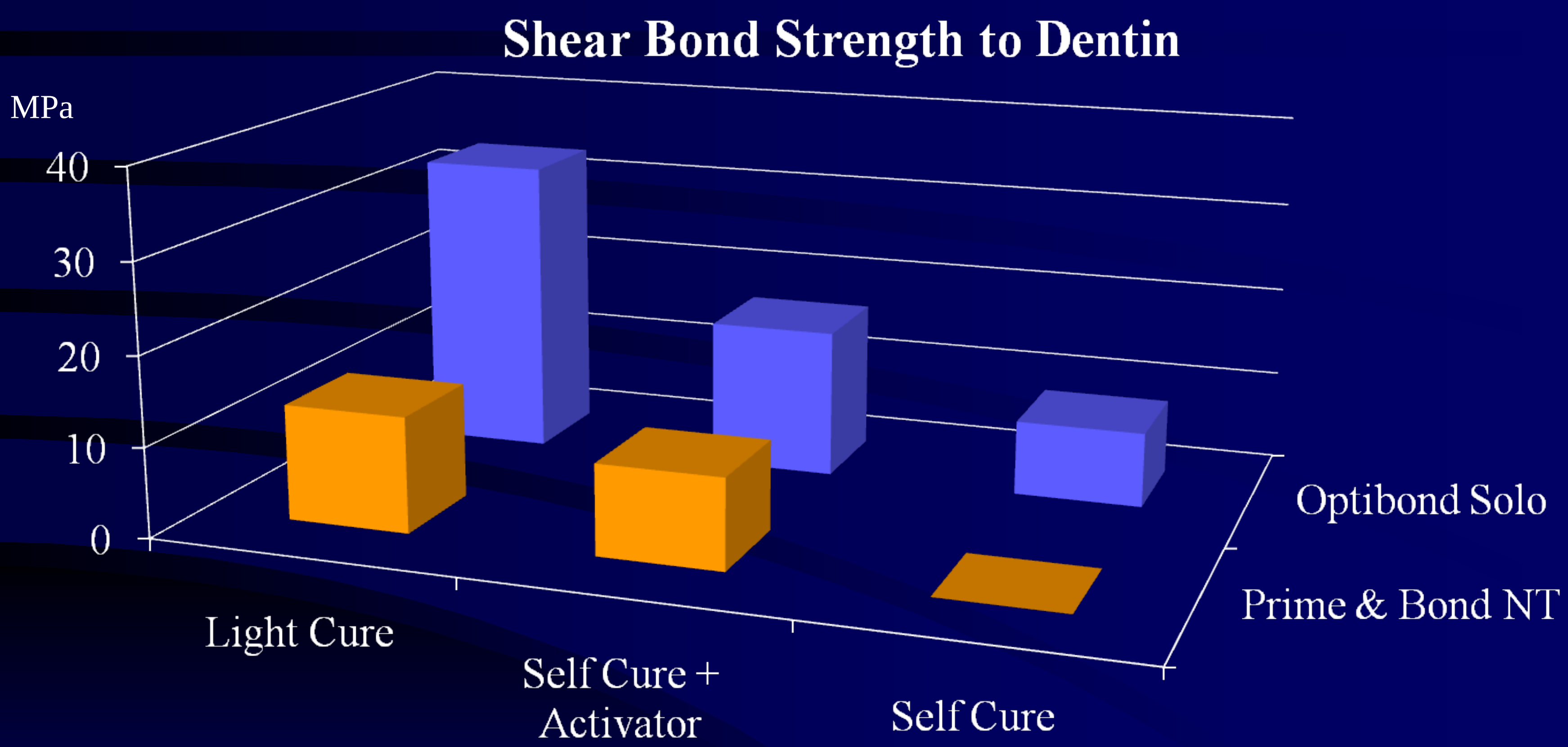


Shade Oper Dent 2014

Dual Cure Activators

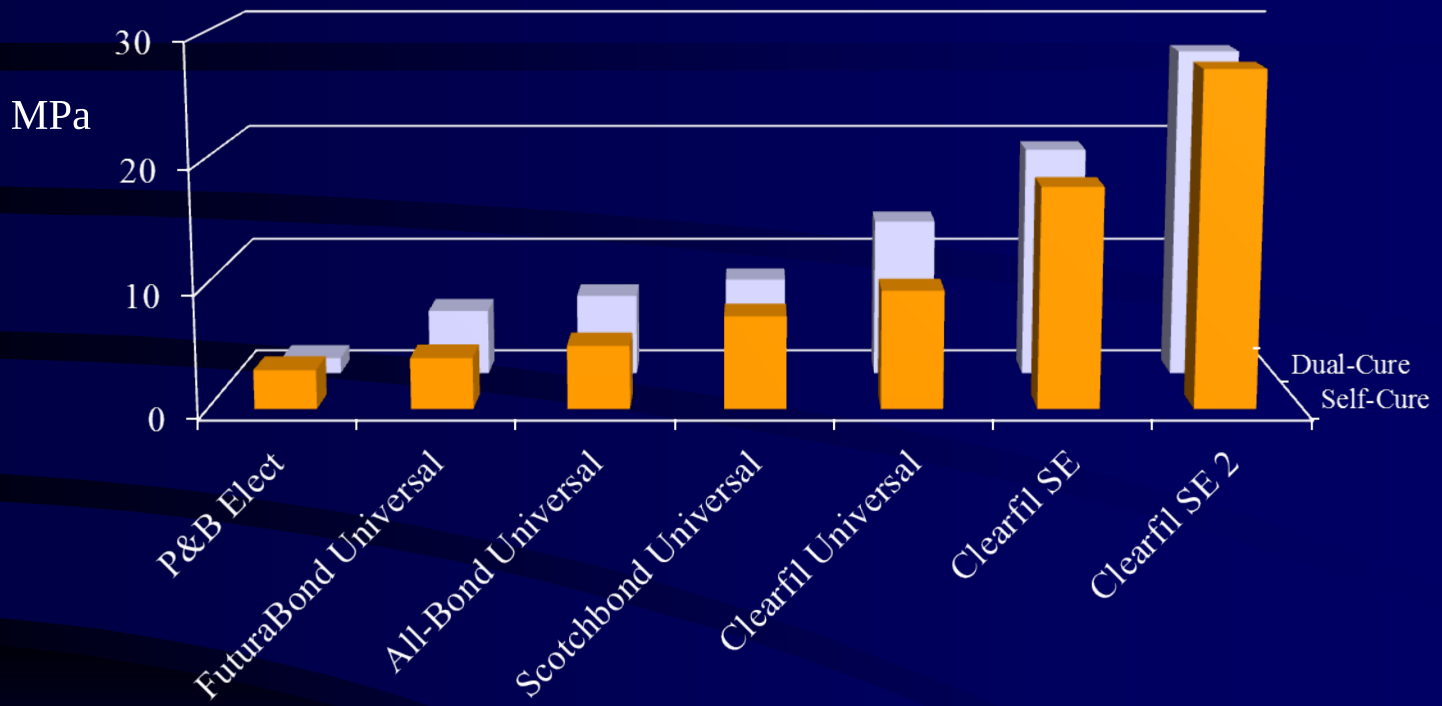
- Dual- and self-cure composites
  - cores
  - cements
- Separate activator
  - aryl sulphinic acid
- Examples
  - Optibond Solo Plus
  - Prime and Bond NT

Laboratory Study



Walter Am J Dent 2009

Universal Adhesives



- Reduced bond strength to dentin with resin cements
  - universal < non-simplified
  - self-cure < dual-cure

Raimondi Am J Dent 2016

Cementation

(Oxide Ceramics)

- Conventional cements
- Bonding
  - air-abrasion
    - resin cement
      - functional monomers (MDP)
  - tribochemical silica coating
    - silica-enriched aluminum oxide
    - silane primer
    - resin cement
  - ceramic primers
    - functional monomers (MDP)
    - resin cement

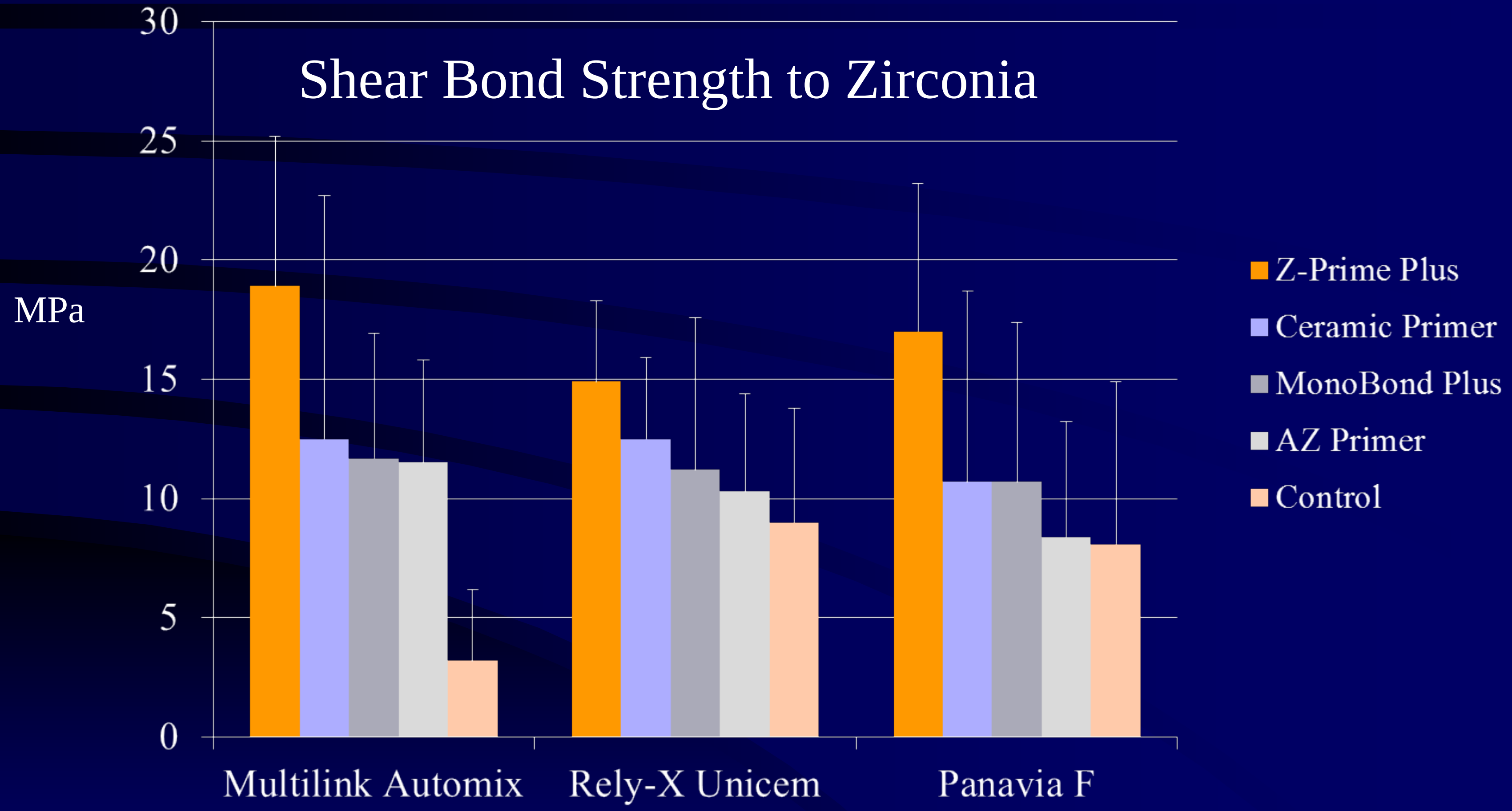
Tribochemical Silica Coating

- Creation of a chemical bond with mechanical energy (frictional)
  - very high temperatures
- Micro-mechanical roughening
- Silicatized coating
  - CoJet, Rocatec (3M ESPE)
- No durable bond to zirconia
  - Kern Dent Mater 2014

Bifunctional Monomers

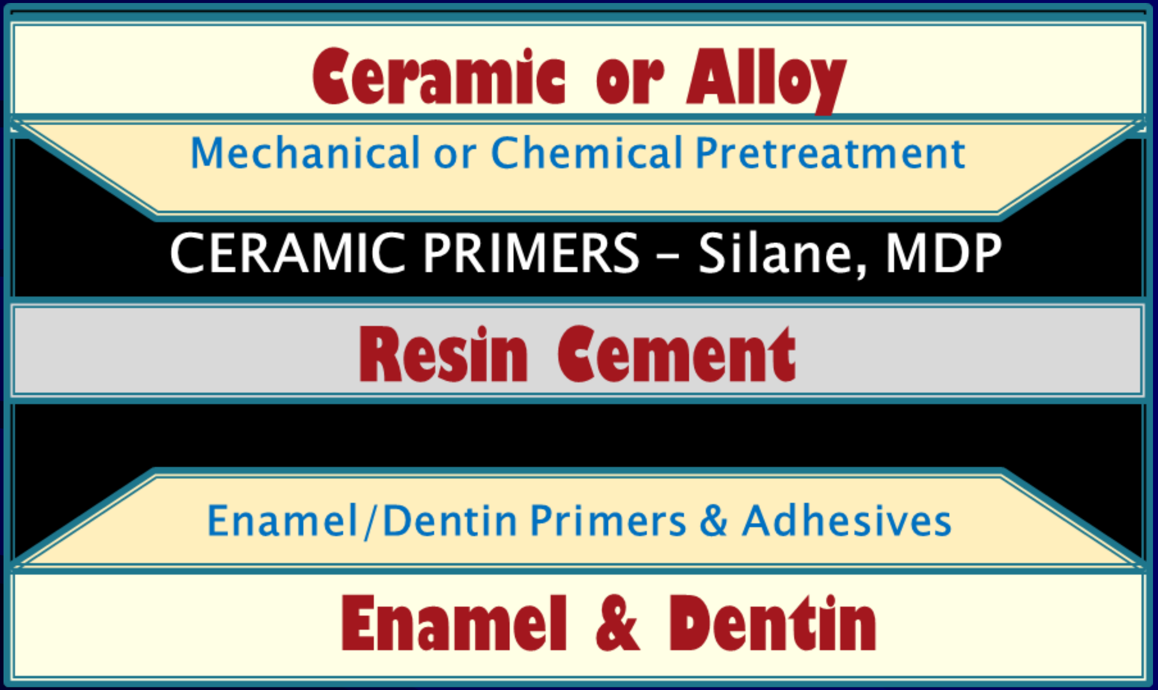
- MDP
  (10-methacryloyloxydecyl dihydrogen phosphate)
  - cements
    - Panavia (Kuraray)
  - primers
    - Z-Prime (Bisco)
- 4-META (4-methacryloyloxyethyl trimellitate)
  - cements
    - C&B Metabond (Parkell)
  - primers
    - Porcelain Liner (Sun)

Ceramic Primers



Kobes Gen Dent 2013

Bonding Interface



Slide from Col Jessup

Resin Cements

- Advantages
  - High tensile strength
  - High compressive strength
  - Bonds to tooth and restoration
    - monoblock
  - Low solubility
- Disadvantages
  - Potential allergen
  - Pulpal sensitivity
  - Technique sensitive
  - Cost

Resin Cements

- Composition
  - Cross-linking monomers
    - Bis-GMA or urethane dimethacrylate resin
  - Functional monomers
    - MDP, 4-META
  - Inorganic fillers
    - silica, barium glass, ytterbium trifluoride
  - Initiators, activators, inhibitors, pigments

Resin Cements

- Classification
  - polymerization mechanism
    - self cure
    - light cure
    - dual cure
  - surface treatment
    - etch-and-rinse
    - self etch
    - self adhesive
  - monomer type
    - esthetic
    - adhesive
    - self adhesive

Self Cure

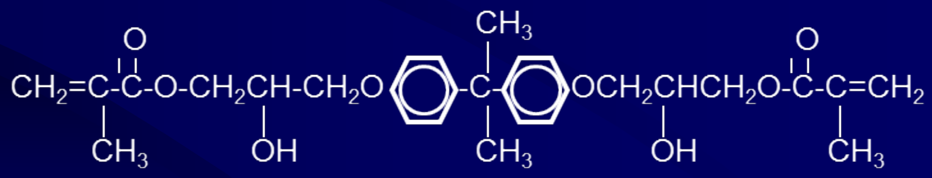
- Does not react with a light
- Mix separate pastes
  - benzoyl peroxide initiator
  - tertiary amine activator
- Free radicals produced
- Radicals attack carbon double bond of monomer

Self-Cure Cements

- Useful where light can not penetrate
  – resin-bonded fixed partial dentures
- Fast, strong set
- Air-inhibited
- Excess cement difficult to remove

Light Cure

- Photo-initiator in resin
    - camphorquinone
  - absorbs photon energy
  - combines with activator
    - amine
  - creating free radicals
  - initiates polymerization
    - monomer
      - Bis-GMA



Light Cure

- Advantages
  - longer working time
  - greater polymerization
  - greater color stability
- Disadvantage
  - light attenuation through restoration

Light-Cure Only Cements

- Light must reach cement
  - ceramic veneers
- Multiple shades

Dual-Cure

- Both reactant types
  - light cure
  - self cure
- Polymerize with / without light
  - ceramic inlays, onlays, crowns, FPDs, posts
- Less polymerization if not completely light cured

Dual-Cure Cements

- Dual-cure only
  - limited shades
  - marketed for posterior ceramic restorations
- Dual-cure option
  - more shades
    - light cure
      - veneers
    - dual cure
      - anterior/posterior ceramic restorations

Dual-Cure Cements

- Versatile adhesive bonding
  - self-etch
  - etch-and-rinse
  - selective etch

Esthetic Resin Cements

- Cross-linking monomers only
- Requires bonding agent
  - bonding to tooth substrates
- Requires separate primer
  - any ceramic material
    - MDP or silane
- Light-, dual-cured
- Stronger mechanical properties
  - than self-adhesive resin cement
- Multiple shades available

Powers: Guide to Zirconia Bonding

Adhesive Resin Cements

- Contains acidic and crosslinking monomers
- Requires bonding agent
  - bonding to tooth substrates
- Requires separate silane
  - glass-ceramic restorations
- Can bond directly to zirconia or base-metals
  - functional monomer
    - MDP
- Stronger mechanical properties
  - than self-adhesive resin cement
- Dual- or self-cured

Powers: Guide to Zirconia Bonding

Self-Adhesive Resin Cements

- Contains acidic monomers
- Self-etching
  - no bonding agent
    - MDP bonds to mineral content of dentin
- Requires separate silane
  - glass-ceramic restorations
- Can bond directly to zirconia or base-metals
  - functional monomer
    - MDP
- Weaker mechanical properties
  - esthetic or adhesive resin cements
- Dual-cured
- Limited shade selection

Powers: Guide to Zirconia Bonding

Post-Cementation Sensitivity

- Two self-adhesive cements
  - RelyX Unicem (3M ESPE)
  - Breeze (Pentron)
- One etch-and-rinse cement
  - RelyX ARC
- Tested to cold, air, biting
  - 24 hrs, 2-, 6-, 12 weeks
- Self-adhesive cements
  - significantly lower sensitivity

Saad JADA 2010

Post-Cementation Sensitivity

- Self-adhesive vs. RMGIC
  - iCem (Heraeus Kulzer)
  - Fuji Plus (GC)
- Tested to cold, air
  - Baseline, 24 hrs, 1 wk, 3 wks
- Self-adhesive cement
  - significantly lower sensitivity

Blatz Clin Oral Investig 2013

Post-Cementation Sensitivity

- Self-adhesive vs. GIC
  - SmartCem 2 (Dentsply)
  - Fuji I (GC)
- Visual Analog Scale
  - Baseline, 24 hrs, 1 wk
- Self-adhesive cement
  - significantly lower sensitivity at 1 wk

Shetty J Contemp Dent Pract 2012

Self-Adhesive Resin Cements
(Selective Enamel Etch)

- *In vitro*
  - significant improvement in bond strength
    - De Munck Dent Mater 2004
    - Hikita Dent Mater 2007
- *In vivo*
  - equivocal
    - inlays: no significant clinical difference after 4 yrs
      - Peumans Clin Oral Invest 2013
    - onlays: better survival after 6.5 yrs
      - Baader J Adhes Dent 2016